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COCOA

by

D. H. URQUHART
B.Sc. (Agric.)

Formerly Director of Agriculture in the Gold Coast

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FOREWORD

by

Sir Geoffrey Clay, K.C.M.G., O.B.E., M.C., B.Sc., N.D.A., N.D.D.
Agricultural Adviser to the Secretary of State for the Colonies

COCOA may justly be termed one of the world's most favoured crops, favoured because, while the consumption of cocoa and chocolate is expanding with the rising standards of living, the cocoa tree is distinctly selective as to soil and climate and is particularly susceptible to certain pests and diseases. It is, therefore, no easy matter for the world's cocoa production to be expanded by the opening up of new areas of production and existing producers appear to be favourably shielded at present, and for many years to come, from that fear of primary producers of any major staple commodity that production will exceed consumption.

Because of the selective nature of the cocoa tree attempts to establish new areas must be backed by the fullest knowledge of its optimum environment, the systems of cultivation which by experience and scientific investigation have been established in the various cocoa growing areas of the world either by peasant smallholders or on large estates, the diseases and pests to which the plant is subject and the research which is being conducted on the crop.

In recent years, the conferences in London organised by the Cocoa, Chocolate and Confectionery Alliance have provided a valuable forum for the exchange of views and experiences between research workers in cocoa, and between producer representatives and the cocoa and chocolate manufacturers from all over the world. The reports of these conferences contain much practical as well as scientific information, but so far as I know no attempt has yet been made to bring together all the existing information into one book.

It is against this background that I welcome the timely publication of this book on Cocoa as second in the series of books on Tropical Agriculture which are being published with the active encouragement of the Colonial Advisory Council of Agriculture, Animal Health and Forestry. Whilst essentially intended by its author as a practical handbook for cocoa planters, the book will be of undoubted value in any institution concerned with the teaching of tropical agriculture.

In its author, Mr. D. H. Urquhart, we have a man with, I suppose, the widest experience of cocoa growing in the world to-day. Mr. Urquhart spent nearly a quarter of a century in the Colonial Agricultural Service in Nigeria and in the Gold Coast, which together produce a high proportion of the world's cocoa crop. For several years prior to his retirement he occupied the post of Director of Agriculture in the Gold Coast; his appointment to this important post came at a time when drastic action was needed to deal with the catastrophic spread of the swollen shoot virus disease of cocoa which has caused such heavy losses to cocoa growers in West Africa. Mr. Urquhart is, therefore, well qualified from his experience to advise on the development of cocoa production by peasant farmers and the organisation of services to such farmers. In addition, since his retirement in 1950, Mr. Urquhart has, at the instigation of and financed by Messrs. Cadbury Brothers Limited, carried out many missions to existing and potential cocoa growing areas of the world and has thus had a unique opportunity of studying at first hand the conditions and problems present in most of them.

I am sure that the book will receive a most favourable reception from all those, both planters and governments, concerned with cocoa development, and that its value will be reflected in the improvement and expansion of cocoa production throughout the tropical world.

Colonial Office, G. F. CLAY
Sanctuary Buildings,
Great Smith Street,
London, S.W.1.

NOTE

This volume is one of a series of books on tropical agriculture which are being published with the active encouragement of the Colonial Advisory Council of Agriculture, Animal Health and Forestry, under the editorship of Sir Harold Tempany, C.M.G., C.B.E., D.Sc., F.R.I.C., formerly Agricultural Adviser to the Secretary of State for the Colonies and previously Director of Agriculture in Mauritius and Malaya.

Already published:
Rice, by D. H. Grist.

Other volumes in preparation:
Introduction to Tropical Agriculture, by Sir Harold Tempany.
Tea, by T. Eden.

PREFACE

I AM indebted to people in various countries for generous help and my thanks are due to them for providing valuable information for this book.

In Britain I am chiefly indebted to the firm of Cadburys for giving me every facility to write the book, and I have been greatly assisted not only by the encouragement of their Board, but by much technical advice and help from my Bournville colleagues. They have read the drafts of appropriate sections and corrected the proofs, and during my absences abroad have watched over the preparation of the material on my behalf. I would list the following to whom I am especially indebted: Mr. John Cadbury, Mr. W. E. Cossons, Mr. Spencer L. Hale, Mr. W. McL. Hood, C.B.E., Dr. G. R. Howat, Mr. F. T. Lockwood, Miss D. M. Stevens, Mr. R. V. Wadsworth, and Mr. G. A. Ross Wood. I have had valuable advice from Mr. D. L. Martin, a director of Unilever, who is responsible for guiding the immense plantation interests of that company. I have had the advantage of consultations with Dr. A. F. Posnette, whose outstanding work in research in cocoa is well known.

The value of the book is greatly enhanced by the inclusion of the chapter on Virus Diseases by Dr. A. F. Posnette, East Malling Research Station, and the chapters on Rehabilitation, Botany, and Soils, respectively by Professor C. Y. Shephard, C.B.E., Professor R. E. Baker, and Professor F. Hardy, C.B.E., all of the Imperial College of Tropical Agriculture, Trinidad.

The subject matter of the chapter on Vegetative Propagation of Cocoa by Rooted Cuttings, etc., is based mainly on the work of Dr. Harry Evans in Trinidad, supplemented by some of his unpublished writing and information provided by his successor, Mr. Dennis Murray. Mr. Moll, of the Trinidad Cocoa Board, supplied information on large-scale production of cuttings.

Much of the information included in the chapters on The Cocoa Plantation is derived from discussions with experienced planters in Trinidad, particularly Mr. Carl de Verteuil and Mr. Neal Fahey, who generously placed at my disposal knowledge gained from many years of practical work.

In the Gold Coast, I received help from members of the Department of Agriculture, notably Mr. James D. Broatch, Deputy

Director; Mr. P. S. Hammond, M.B.E., Assistant Director; Mr. John Paine, formerly of the Department, and Mr. Victor Osei, all of whom are authorities on cocoa culture in West Africa.

I am grateful to Sir Harold Tempany, C.M.G., C.B.E., for ready help and guidance.

Finally, I acknowledge the assistance of my wife who helped me in the work throughout.

The author takes responsibility for views expressed in the book.

D.H.U.

Bournville,
August, 1954.

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Information as to previous publications may not be complete, but the above list is believed to be accurate.

Chapter I

INTRODUCTORY

The Origin of Cocoa—Development of New Sources of Supply of Cocoa—Developments in Cocoa Consumption—Expansion of the Production of Cocoa—The Prospects for Cocoa.

THE ORIGIN OF COCOA*

COCOA and chocolate are derived from the seeds of *Theobroma cacao*, a small tree indigenous to the forests of Central and South America.

The existence of cocoa as a cultivated crop dates back to the remote past in that region; the Maya Indians of Central America had an intimate knowledge of cocoa cultivation long before the Spanish conquest in A.D. 1519. In his letters to Charles V, the reigning Spanish monarch, Cortes, the Spanish conqueror of Mexico, refers to cocoa cultivation and the use of the product as an article of diet by the Mayas and Aztecs.

It is recorded that the Maya Indians used to make a drink from the seeds of cocoa by pounding them with maize and boiling the mixture with capsicum in water. The Spaniards, apparently, did not like this decoction and devised a method of mixing the powdered beans with sugar and brewing a drink which was more to their taste. They introduced this mode of consuming cocoa, with the product itself, into Spain. At first exports to Spain consisted of the beans mixed with sugar and spices, but later the beans were exported in their natural state.

It was not, however, until the end of the sixteenth century that a taste for cocoa became firmly established in the Old World. About that time cocoa is first mentioned in shipping documents and it had become a not unimportant item of commerce.

In the early years exports came only from Central America and were exclusively confined to Spain, owing to the policy of the Spaniards of restricting trade with the Americas solely to exports to that country. Later, however, exports of cocoa began to come from Venezuela. This was the result of the intervention of the Dutch,

* The spelling COCOA is used throughout the book, except where the botanical form CACAO is quoted, e.g. in the authorities mentioned in Chapters II and V.

who had established themselves on the island of Curaçao off the Venezuelan coast and commenced the export of Venezuelan cocoa to Holland.

From being originally confined to Spain, cocoa drinking had, by the early seventeenth century, spread among all the great nations of Europe. The trade in cocoa had by then fallen largely into Dutch hands although the countries of production were controlled by Spain.

Cocoa consumption was in those days confined to the form of drinking chocolate, and was restricted to the wealthier sections of the community, by reason of its high price. Chocolate drinking was very popular at many European courts, e.g. at the courts of Charles II in England and Louis XIV in France.

DEVELOPMENT OF NEW SOURCES OF SUPPLY OF COCOA

The increasing popularity of cocoa caused the tree to be introduced into various other tropical countries. The Spaniards are reported to have introduced it into Trinidad in A.D. 1525; there are legends that the tree is indigenous to that island, but this is doubted. It spread subsequently to most of the other West Indian islands where conditions are suitable. The Spaniards are also reported to have introduced cocoa into the Philippines in A.D. 1670, while they are also alleged to have introduced it into Celebes as early as A.D. 1580. Its spread through what is now Indonesia was, however, probably due to the Dutch, who are also credited with having introduced it into Ceylon, although there is no record of the exact date.

It is probable that the Dutch also introduced cocoa into São Tomé, an island in the Gulf of Guinea, which was occupied by them from 1641 to 1844, when it reverted to the original discoverers, the Portuguese. Historically, this is of importance because it was from São Tomé that cocoa was said to have been introduced into West Africa in the latter part of the nineteenth century.

Cocoa production extended during the seventeenth century throughout the West Indian islands and began to gain ground in overseas markets, but the industry suffered a severe setback in 1727 when a hurricane destroyed many plantations.

Cocoa production in South America was for long confined to Venezuela, owing to restrictions imposed by Spain; it was only when the Spanish grip began to slacken at the end of the eighteenth century that developments began to occur in other South American countries. The first country to develop an export trade after Venezuela was Ecuador. Further developments were delayed by the South American wars of liberation but subsequently developments proceeded fairly

rapidly, and exports appeared from Colombia, Peru, Bolivia and the Guianas.

From Brazil, however, which is now by far the largest exporter of cocoa in the Western Hemisphere production remained insignificant during the earlier part of the nineteenth century. Until the 1890's the Amazon basin was the foremost producer and exporter of cocoa in Brazil. In 1851 exports of cocoa from Amazon ports totalled 2,900 tons and this had increased to 6,900 tons by 1891.

DEVELOPMENTS IN COCOA CONSUMPTION

Until the nineteenth century cocoa was consumed only in the form of drinking chocolate, made from the crushed beans. These contain over 50 per cent of fat (cocoa butter) which makes beverages prepared from the beans unpalatable and difficult of digestion. To counteract this it was customary in the early days to mix the powdered beans with some floury or farinaceous substance in order to counteract the excess of fat.

An event which powerfully influenced the consumption of cocoa in Europe and America was the invention, early in the nineteenth century, by C. J. van Houten in Holland, of a process whereby the fat could be extracted from the cocoa bean. Thus arose the manufacture of drinking cocoa or chocolate from which most of the fat had been removed, thereby increasing its palatability and digestibility. At the same time it paved the way for the production of eating chocolate. This product is prepared by adding sugar, flavourings and additional cocoa butter to ground cocoa nibs. A later development was the invention of milk chocolate, the most popular form of eating chocolate to-day, in which the cocoa and other constituents are compounded with the solids of dairy milk.

These new products met with popular favour and their manufacture was taken up on a large scale in Europe and America. As a result the demand for cocoa expanded enormously during the latter years of the nineteenth and the first half of the twentieth centuries.

THE EXPANSION OF THE PRODUCTION OF COCOA

To meet this increasing demand, which naturally led to cocoa commanding very high prices on world markets, cocoa production also increased very rapidly. By 1900 cocoa production had increased to over 100,000 tons annually, derived for the most part from America and the West Indies, although by then Africa was making substantial contributions to production, with small amounts from Asia and Australasia.

The development of cocoa production in West Africa proceeded with astonishing rapidity. It proceeded from the introduction into the Gold Coast of cocoa planting material from São Tomé by a native African cultivator. From this introduction the great industries of the Gold Coast and Nigeria are largely derived. The expansion of cocoa planting in the state of Bahia in Brazil dates from the closing years of the nineteenth century. It was the outcome of the abolition of slavery on the sugar estates of Brazil in 1888. Large numbers of liberated slaves at that time emigrated to Bahia, where cocoa growing already existed on a small scale, and they started growing cocoa on small holdings, encouraged by the high prices for cocoa then prevailing.

The remarkable manner in which world cocoa production has expanded since the beginning of the twentieth century was well summarized by Mr. L. A. Byles in an address to the 1951 Cocoa Conference organized by the Cocoa, Chocolate and Confectionery Alliance, in the following words:

"In 1900 America produced about 81 per cent and Africa 16 per cent of world cocoa supplies. To-day Africa produces on the average about 65 per cent of the world's cocoa and has done so for the last twenty years. America, including the West Indies, produces about 34 per cent and Asia only 1 per cent. At the turn of the century the leading producers were Ecuador, Brazil, Venezuela, São Tomé and Trinidad. In the five years immediately preceding the first world war Ecuador, São Tomé, the Gold Coast and Brazil competed for the first place amongst the world's cocoa producers. In the five years preceding the second world war the Gold Coast had outstripped competitors, with Brazil following and Nigeria some way behind. The Ivory Coast and the French Cameroons were expanding production rapidly and were well ahead of both Ecuador and São Tomé where production had fallen greatly.

"To-day the Gold Coast produces about 35 per cent, Brazil 17 per cent, Nigeria 14 per cent and the French Cameroons 6 per cent of the world's cocoa supplies. The past fifty years have therefore seen a vast shift in the leading centres of production."

It may be added that world production is now averaging between 650,000 and 750,000 tons of cocoa per annum.

THE PROSPECTS FOR COCOA

In the past twenty years world production of cocoa has ceased to expand at its former rapid rate and is approximately static, mainly by reason of the heavy toll taken by diseases and pests in Africa and

America. This has led to shortages of supply owing to the expansion of the demand with population growth, and has affected prices for cocoa which of recent years have risen to unprecedented levels.

Cocoa is at present one of the most profitable crops that can be grown for export in the tropics, and it seems reasonable to presume that profitable markets may be expected to continue to exist for many years to come. In the past, supplies of raw cocoa exceeded demand at times and this led to low prices, partly, it may be conceded, because at that time manufacture and distribution had not been geared to the unforeseen rapid expansion of production, To-day, however, production is balanced by improved and expanded organization for manufacture and distribution and the industry is well equipped to deal with further expansion of production, should the need arise.

The restrictions which the present high prices for cocoa threaten to impose on the consumption of eating chocolate and other cocoa products, can only be countered by an increased world production. The present limitation to this is imposed by the incidence of pests and diseases. It seems reasonable to expect that the skill of the scientists, which has successfully overcome similar difficulties in other agricultural industries, will ultimately succeed in surmounting them in the case of cocoa.

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Chapter II

THE BOTANY OF COCOA*

History of Cocoa Planting—Natural Habitat—Habit of Growth—Types of Branches—The Leaves—The Flowers—Pollination—The Fruit—Cocoa Varieties—Nomenclature of Cocoa—Present-day Classification.

HISTORY OF COCOA PLANTING

THE genus *Theobroma* is indigenous to the New World, and wild species occur from Mexico to Peru, with an apparent centre of origin in the upper Amazon basin. The cocoa tree, *Theobroma cacao L.*, belongs to the lower storey of the lowland forests where conditions are warm, shady, and humid. It has been cultivated since prehistoric times by the Indians of South and Central America and opinion is divided as to whether it now ever occurs in a truly wild state or only in areas which have at some time or other been interfered with by man. The Spaniards who landed in Mexico early in the sixteenth century found cocoa an established product with every indication that it had been used, and therefore presumably planted, for centuries. The crop, as grown to-day, is much more complex than that known to the Mexicans, but in spite of its development having taken place relatively recently, its botanical history is by no means clear.

The Spaniards are said to have planted cocoa in Trinidad as early as 1525, but it is not known whence they obtained planting material. There is no good evidence that the tree is native to Trinidad, though a few wild trees can be found in the forests. These are presumably escapes from early cultivation and actually bear sufficient resemblance to Mexican forms to suggest that there may have been an early importation. Cocoa was certainly being shipped from what is now Venezuela in 1634 and the material planted there is likewise uncertain. There was probably a native cocoa in the forests which may have been used, as well as material from the same source as the Trinidad plantings. The cocoa called "Criollo" (or native) in Venezuela to-day is rather different from the Mexican type.

Venezuela was the chief producer until about 1830, when it was passed by Ecuador. A native Ecuadorean type, quite distinct from

* By Professor R. E. Baker.

the Venezuelan, was planted in the latter country. Trinidad was at that time the third largest producer after Venezuela and Ecuador and was producing a type of cocoa quite different from either. All three, however, were producing what are now classed as fine or high-flavour cocoas.

The Gold Coast started planting cocoa about 1879 with yet another distinct type of material, obtained indirectly from Brazil or Surinam, of a different flavour but superior in hardiness and yield. It is misleading to speak of the cocoas of Venezuela, Ecuador, and Trinidad as "high quality" and those of West Africa as "inferior quality." Different kinds of cocoa have different flavours and therefore different uses, but much West African cocoa is now better prepared, and therefore could be said to be of better "quality" than the present-day produce of the older cocoa-growing countries.

NATURAL HABITAT

Ecologically, all varieties of cocoa appear to be trees of lowland tropical forests. Their natural habitat includes very wet spots in the lowest storey of small trees in dense rain forest. The limits of cultivation are about 20° N. and 20° S., with the bulk of the crop within 10° of the equator, and within these limits most of the main producing areas are at low elevations, usually below 1,000 feet. Cocoa, however, grows well in the Cauca valley of Colombia at 3,000 feet, though that is probably near the limit. The minimum annual rainfall for successful cultivation seems to be about 50 inches, but distribution of rainfall and shelter from wind are more important factors than total precipitation.

The origin of the tree as an under-storey species in forest is probably responsible to some extent for the traditional method of growing it under the shade of larger trees, but it is to be noted that in this respect the "natural" environment does not necessarily give the best conditions for high yield. In fact, the heavily shaded trees in forest usually carry little fruit. Cocoa can survive in heavy shade that would kill many species, but it can also survive a considerable degree of exposure, although general experience is that unshaded cocoa may suffer severe set-backs. The lesson to be learnt from the forest habitat and from experience in cultivation seems to be the necessity for protection from wind and the desirability of shade, except in those instances where experience has shown that shade may be safely omitted.

HABIT OF GROWTH

The various kinds of cocoa differ little in general habit. All are small trees, attaining a height of thirty feet or so, and with few exceptions they all have an uncommon and characteristic mode of branching. The seedling plant forms a straight main stem three to five feet high, and then forks into three, four, or five main, almost horizontal, limbs, forming the so-called fan or "jorquette." The terminal bud is used up in the forking, and further increase in height is made by a sucker or "chupon" which arises later, usually just below the jorquette, and grows up vertically between the branches of the latter to repeat, a few feet higher up, the forking of the main trunk and form a second storey. An unpruned tree may add a third, or even a fourth tier of branches, and plantation practice varies, so that on different estates one may see trees kept to one jorquette and trees with two or three. In certain wild *Theobroma* species the terminal bud is not used up in branching, and growth continues from above the jorquette, giving the tree a distinctive and very regular appearance.

Types of Branches

There are thus two types of branches, (*a*) the upright or chupon type, including the first main axis of the seedling, and (*b*) the fan type. Both bear flowers and fruits, but they differ in several other respects. The chupon type of branch bears its leaves in a $\frac{3}{8}$-spiral, and is determinate in its growth, as sooner or later it always gives rise to a terminal fan. The fan branch has its leaves two-ranked and is indeterminate, growing indefinitely and giving rise to laterals of its own type.

As a general rule, chupons give rise to chupons except in the jorquette, and fans to fans. There is, however, a certain plasticity about this so-called "dimorphism" of branching. It is very rare for a fan to be produced from a chupon below the jorquette, but it is by no means uncommon for chupons to be produced on fans. The exception to this rule is to be found in certain Central American cocoas. These have no chupon branches; the main stem starts from the seed with spirally arranged leaves, but the spiral quickly opens into a two-ranked arrangement with no jorquette, and all subsequent branches are of the fan type. These trees are uncommon in most countries outside Central America, though a few occur in Trinidad.

The Leaves

The leaves of the tree, when mature, are dark green in colour and thin but firm in texture. When young they are light green or of

1. A cocoa farm in the Gold Coast

2. A chupon branch of a cocoa tree with leaves in a $\frac{3}{8}$-spiral giving rise to a jorquette of five fan-branches

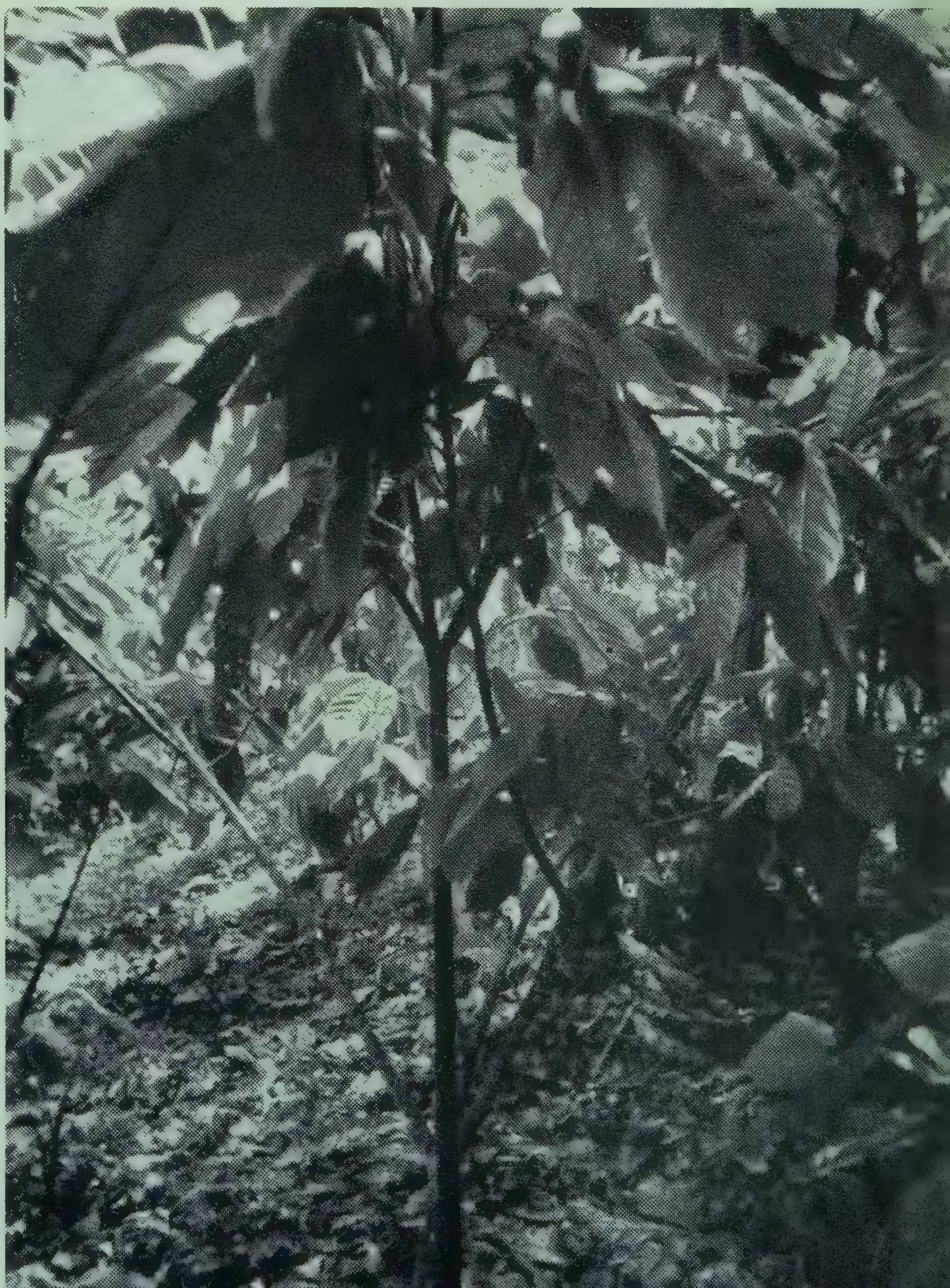
3. Cocoa flower, showing the style surrounded by five pigmented staminodes

4. A fan-branch: The leaves are alternate and in one plane. The pulvini or swellings on the petioles can be seen

5. A collection of cocoa pods
In the background are pods from I.C.S. clones
The group in the middle shows the range of size and shape found on a Trinidad estate
In the foreground are some Calabacillo and Angoleta pods

6. A chupon arising from the base of a mature tree

7. A cocoa tree about seven years old grown from a fan-cutting



8. A chupon arising from a fan-cutting.
The latter may be removed shortly and the new tree will then develop as if it were a normal seedling tree

various shades of red, and very soft and limp, hanging vertically from their petioles. Stipules are conspicuous on the young leaves but are soon shed.

The petiole has a well-marked pulvinus or swelling at each end, possibly facilitating the turning of the leaf in response to phototropic stimuli. The fan branches make their growth in "flushes," the length of the internodes gradually increasing from start of growth up to a maximum, and decreasing again as the bud returns to a dormant condition. The stipules of the last-formed leaves of a flush, being close together, leave characteristic scars on the twig when growth is resumed, so that the extent of successive flushes can easily be seen on examination of a branch. The leaves usually persist through two flushes and are dropped from the third length back from the terminal bud, so that there are normally leaves of three distinct ages on each branch.

Flowers

Theobroma cacao is "cauliflorous," which means that the flowers and fruits are produced on the older leafless parts of the stem and branches. In some *Theobroma* species, such as *T. bicolor*, the flowers are produced in the leaf axils of the current shoots. In *T. cacao*, although the flowers are produced on the old wood, they arise at spots which were originally leaf axils. According to Stahel, they occur in the axils of the reduced first leaves of the axillary branch, which then normally develops no further. Occasionally on healthy trees, and more frequently on trees attacked by witches' broom disease (*Marasmius perniciosus*), the axillary branch develops into a small leafy shoot, and in such cases the position of the inflorescence is very clear.

The flower is quite regular and hermaphrodite, and has the formula $K5\ C5\ A5 + 5\ G(\underline{5})$, or in other words, five sepals, five petals, ten stamens in two groups or whorls, only one of which is fertile, and a superior ovary of five united carpels. The pink or whitish sepals are valvate in arrangement; the petals are very narrow at the base and expanded above into a cup-shaped pouch, beyond which they end in a relatively broad spatulate tip or ligule. The androecium or male part of the flower consists of five long, pointed staminodes and five fertile stamens which, being the inner whorl, stand opposite the petals. All ten are joined at the base into a very short tube. The stamens are so bent that their anthers lie concealed in the pouched portion of the corresponding petals, whilst the staminodes stand erect and form a sort of ring fence around the style. The stamens are double, each representing two, fused along their filaments, and

each has therefore four pollen sacs. The ovary is simple, having five compartments containing numerous ovules which are arranged around a central axis in the ovary, and the style is partially divided into five stigmatic lobes, which usually more or less adhere together. There is a constriction, at which the flowers absciss, at the base of the pedicel.

POLLINATION

The pollination mechanism of cocoa is still imperfectly understood, and presents features of much interest. A conspicuous feature is the enormous wastage of flowers which normally occurs, and examination shows that the vast majority are never pollinated. As a rule, according to several independent estimates, the proportion of pollinated stigmas is about 5 per cent.

There is no record of what the natural pollinating agent in the native haunts of the tree may be, and if the flower is examined critically the conclusion must be formed that the structure is not such as to facilitate pollination by any of the regular means, but rather to hinder it. There is neither scent nor nectar to attract insects and, on the other hand, the pollen is too sticky to be that of a wind-pollinated plant, neither is the position of the anthers suitable for such a habit, but distinctly the reverse. In fact, both the position of the anthers, hidden in the pouched petals, and the ring-fence of staminodes hindering access to the stigmas, are features incapable of being regarded by any stretch of a teleological imagination as facilitating pollination.

Several investigations in recent years (Harland, 1925; Stahel, 1928; Billes, 1941; Posnette, 1944) have shown fairly conclusively that pollination is effected by the agency of insects. A certain amount of self-pollination is effected by small crawling insects, such as flower thrips and aphides. These, however, are evidently not the only agents. Flowers on sections of the trunk protected against crawling insects by sticky bands show a certain number pollinated, presumably by a flying insect. Furthermore, it has been known since 1931 that many trees in the Trinidad population are self-incompatible (i.e. set no fruit with their own pollen) yet some of these are heavy yielders. Clearly there must be some agent, presumably winged, conveying pollen from tree to tree. Billes found that a Ceratopogonid midge of the genus *Forcipomyia* pollinated cocoa in Trinidad. Two species —*F. quasi-ingrami* and *Lasiohelea nana*—have since been identified in Trinidad and different species of the same genera have been found in West Africa, but there may be other winged pollinators, and the

subject needs still more investigation. Unpollinated flowers are usually shed the day after opening.

The Fruit

The fruit, which is botanically a berry, usually contains from twenty to forty seeds, each surrounded by a pulp which is developed from the outer integument of the ovule. The outer layers of cells of this integument become prismatic in shape during the growth of the seed, and their contents become highly mucilaginous. At full ripeness they break down and release the mucilage. At lease one important function of the fermentation to which the beans are subjected after harvest is the removal of this mucilage by the action of yeasts; this facilitates subsequent handling and drying of the beans.

As the ripe pods do not open and scatter the seed, nor drop off the tree, and as the seed will presumably be dead by the time the pod is decayed, natural dissemination can only be carried out by animals. Monkeys, rats and squirrels will open the pods for the sake of the beans from which they suck the surrounding sweet pulp before spitting them out.

COCOA VARIETIES

In the brief history of the crop already given, it was recorded that the first exporter of cocoa to the European markets was Venezuela, and for this reason it is hardly surprising that the terminology of the markets is still based on standards applicable to Venezuelan cocoa more than a century ago. This terminology must be understood.

From the earliest plantings in the late sixteenth and early seventeenth centuries up to about 1825, Venezuela grew only one kind of cocoa. It was not a highly uniform variety because the pods from different trees varied in colour (some red and some yellow) and to some extent in size and shape. There was, however, a general and fairly close similarity between them. The pods were relatively long and narrow, pointed, conspicuously ridged and furrowed, and warty. The seeds inside were almost round in cross-section and, when cut across in the fresh state, either white or pale violet in colour. The quality was high; in fact, it has never been surpassed, and the small quantities of this same cocoa now available on the world's markets are still regarded as the highest quality of all cocoas.

About 1825 another kind of cocoa was introduced into Western Venezuela from Trinidad. This was much less uniform and included trees bearing pods that were shorter and relatively broader than those of the old cocoa, less sharply pointed or in some cases not pointed at

all, less conspicuously ridged and furrowed, and often entirely unwarted. Above all, the seeds were somewhat flattened in cross-section and when cut across showed a deep purple colour in the cotyledons. This new cocoa was welcomed because it was hardier than the old kind, grew more strongly, and yielded more, and it was soon extensively planted. To distinguish the two kinds, the older was called "Criollo" (native) and the newer "Forastero" (foreign) or "Trinitario" (the cocoa of Trinidad).

The cocoa from Trinidad, though in the "Fine" category, was distinctly inferior to the more delicate Venezuelan Criollo. So it soon came about that on the European markets "Criollo" became synonymous with "highest quality" and "Forastero" with "lower quality." Trinidad cocoa from Trinidad naturally fell into the "Forastero" group in the trade sense, but so did the cocoa from Ecuador, which at that time was becoming increasingly important. The Ecuador cocoa was entirely different, botanically, from that of Trinidad or the "Trinitario" of Venezuela. Furthermore, it was a native of Ecuador and therefore, in the literal Spanish sense (but not in the trade sense), "Criollo" there. The Ecuadoreans, however, happen to use the word "Nacional" rather than "Criollo" to indicate its indigenous status, and so the confusion does not arise. But the original meanings of "Criollo" and "Forastero" were lost from that time on in the cocoa market, and the words have to be completely re-defined to-day in their application to cocoa varieties.

NOMENCLATURE OF COCOA

The "native" (or long-established) cocoas of Mexico and Central America have white beans and are essentially similar to Venezuelan Criollo, though superficially distinguishable. They scarcely enter the export market but to the extent that they do are classified as "Criollo" and are also classified agriculturally as Criollos. The original Venezuelan Criollo was introduced to Ceylon, Java, Madagascar, and Samoa, and the produce of these countries came on the market as "Ceylon Criollo," "Java Criollo," etc., although the terms, taken literally, would be absurd.

It should be noted that the distinction between "Criollo" and "Forastero" is *not* the distinction between "Fine" and "Ordinary." All the cocoas so far mentioned are "Fine" cocoas in the modern sense. The distinction of "Fine" and "Ordinary" is a later development, rendered necessary by the increasing complexity of the cocoa crop as production spread; and it is that complexity which necessitates this lengthy explanation.

Confusion arose when, about the beginning of the twentieth century, there came on the market from West Africa and Brazil cocoa of another new kind, different from that of any of the Forastero cocoas hitherto known. It was quite naturally grouped for convenience with the Forastero (or "lower quality") cocoa, and the term now included three separate qualities: (*a*) Trinidad cocoa, and Trinitario of Venezuela, (*b*) Cacao Nacional of Ecuador, (*c*) West African and Brazilian cocoas. As the last group increased in production it came to dominate the whole market.

We may briefly summarize in a slightly different manner all the cocoas on the market today as follows: (1) Criollos, the finest of the "Fine," but almost negligible in quantity, which will apparently disappear altogether unless special steps are taken to preserve them. (2) Fine Forasteros, including Ecuador cocoa, Trinidad cocoa, and cocoa from Trinidad grown in Venezuela, Ceylon, Indonesia, and a number of other countries of small output. (3) Ordinary Forasteros, grown in West Africa, Brazil, and San Domingo.

PRESENT-DAY CLASSIFICATION

Botanically, we recognize three groups which correspond almost exactly with this market division, only the position of Ecuador cocoa being anomalous. These three groups are:

Criollo Cocoas. We define the Criollos by the characters already given for the old Venezuelan Criollo population, which will include also the native or long-established cocoas of Mexico and Central America, and also of Colombia. They have pods either red or yellow in colour when ripe, usually deeply ten-furrowed, very warty and conspicuously pointed; the pod wall is relatively thin and easy to cut, the seeds are plump, almost round in section, and the fresh cotyledons either white or pale violet in colour. The seed characters are the most important, as the whole group is variable and occasional trees may have smooth or scarcely pointed pods, but as a rule all the characters mentioned occur together. Though their early history is entirely obscure, it seems likely that the Central American group was carried up from South America by human agency and is not truly indigenous.

Amazonian Forasteros. The Amazonian cocoas comprise the ordinary cocoas of Brazil and West Africa and the Cacao Nacional of Ecuador. They are called Amazonian because they are apparently distributed naturally throughout the basin of that river and its tributaries. They probably originated around the headwaters, but the cocoas of that region are as yet little known in cultivation.

Variation decreases down the river and the members of the group taken into cultivation in Brazil and carried over to West Africa form a fairly uniform population.

The pods of all Amazonian Forasteros are yellow when ripe, and, in the better-known representatives in cultivation, they are inconspicuously ridged and furrowed, smooth and round-ended or very blunt-pointed. The pod wall is relatively thick and often has a woody layer difficult to cut. The seeds are more or less flattened and the fresh cotyledons are dark violet in colour, sometimes almost black.

As with the Criollos, the seed characters are the most important, and more constant than the pod shape, but they are not invariable. Members of this group, which in some way long ago got over the Andes into Ecuador, evolved into a variety with plumper seeds and paler cotyledons than any other known Amazonian Forastero. That variety is the Cacao Nacional and, on account of those characters it is a "Fine" cocoa on the market, though its botanical affinities are with the "Ordinary" kinds.

Trinitarios. The Trinitario cocoas are botanically a complex group, and to explain them we have to go back to history. It has already been mentioned that the Spaniards are supposed to have planted cocoa in Trinidad in the sixteenth century and that the material planted was possibly from Mexico. It is certain that cocoa was grown in Trinidad in the seventeenth century and that the variety was a Criollo in the modern sense. But in 1727 something happened which in the literature is called a "blast"; and whether it was a hurricane or an epidemic outbreak of disease, it virtually wiped out the cocoa cultivation of Trinidad. Some thirty years later the industry was re-established with planting material of a new and hardier variety of cocoa brought in from Venezuela. Details are lacking, but there can be little doubt that the importation was from Eastern Venezuela, and probably it came from the Orinoco valley. The cocoa concerned was certainly not the Venezuelan Criollo being grown at that time in Western Venezuela. It was hardier but of lower quality. We cannot tell whether it was a fairly uniform Amazonian Forastero or whether it was already a mixture. If uniform, it very soon became mixed by being interplanted with the relics of the old "Trinidad Criollo"; but it seems more likely that it had already become mixed in the Orinoco basin by the overlapping of more than one parental type. However that may be, its characters are those of a hybrid population, and its most outstanding characteristic is its heterogeneity. When some of this cocoa was sent to Western Venezuela about seventy years after its introduction to

Trinidad, it was not recognized there as a Venezuelan variety, and, being quite different from the Criollo grown in that district, was distinguished as Forastero or Trinitario.

The group of cocoas now included under the term Trinitario is important for more reasons than its local connection with Trinidad. When reintroduced to Venezuela, the Trinidad cocoa became popular there because it was hardier and more productive than the high-quality but delicate Criollo. Then cross-fertilization took place with the Criollo trees and when seedlings were raised from them they were no longer pure Criollo. By selection the Criollo was gradually supplanted and to-day very little of it is left in pure stands.

The history of Venezuela was repeated both in Ceylon, which grew Venezuelan Criollo from about 1834 but introduced Trinidad cocoa about 1880, and in Java which appears to have got Criollo cocoa first from Ceylon and then got it mixed with a Trinitario introduction in 1888. The process is continuing to-day in the Central American countries and in Colombia, which have Criollos but have introduced either Amazonian or Trinidad cocoa and interplanted it with their own. Wherever we find a hybrid mixture of recent origin we may, for convenience, call it a Trinitario population. This means that Trinitarios differ according to their different histories and parentages, but all are highly heterogeneous. It is precisely their heterogeneity which makes them of the most interest and also of the most promise to the plant breeder.

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Chapter III

CLIMATE

Rainfall—Temperature and Humidity—Altitude—Meteorological Data.

THE climate which usually prevails in the rain-forest zones of large land masses and on islands in the tropics within about 20° north and south of the equator is usually suited to cocoa. It is not proposed to deal with the subject of climate exhaustively, but to touch on some of the main features which affect the cocoa tree.

RAINFALL

Cocoa is grown where the rainfall is as low as 45 to 50 inches and as high as 200 inches. A rainfall of 45 inches seems to be the lowest in which cocoa has been grown so far without irrigation. There does not appear to be any evidence of what may be the upper limit of rainfall in which the crop may be grown. The tree seems to have considerable capacity for adjusting itself to different conditions of rainfall; for example, in those parts of West Africa where there is a dry season of three months or more, the cropping season is well-defined, and the main crop is borne during three to four months of the year. There are long periods when the tree bears little or no fruit. On the other hand, in the Gazelle Peninsula of New Guinea, where there is no well-defined dry season, the cocoa trees bear fruit all the year round. The total rainfall and its distribution will, of course, have to be considered in relation to the type of soil in which the cocoa is grown. High rainfall on a heavy soil may give rise to waterlogging; a rainfall which is adequate on a heavy soil may be inadequate on a lighter soil.

The theory has been advanced that cocoa benefits from a resting period, i.e., several months of non-bearing, as happens in countries with a marked dry season. This theory seems to be refuted by experience in New Guinea where cocoa trees bear all the year round and where the yields per tree are extremely high.

The distribution of rainfall may have an effect on the seasonal incidence of certain diseases. An important example of this can be found in West Africa where, when the rains are prolonged into what is normally the dry season, there is usually a high incidence of fungoid disease. In the British Cameroons, where a great deal of the crop is borne during the rains, losses of pods through fungoid disease are high.

TEMPERATURE AND HUMIDITY

The cocoa tree, being essentially a tree of the lower forest storey, reacts unfavourably to sudden changes of temperature or humidity. On large land masses the direction and force of the wind at different times of the year may have a considerable effect on both these factors. Wind blowing from the sea will naturally be moisture-laden, but winds blowing from inland, such as the "harmattan" winds from the desert in West Africa, have a drying effect and result in low temperatures at night. Forest belts, windbreaks, and trees providing overhead shade temper the prevailing winds and help to maintain stable conditions of temperature and humidity within the plantation.

ALTITUDE

The main factor limiting the growth of cocoa at the higher altitudes is temperature. Where the range of temperature is suitable, it is possible to grow cocoa up to altitudes of over 3,000 feet. Where the higher altitudes are subject to prolonged periods of mist and overcast skies, the cocoa trees are more liable to suffer from fungus diseases.

METEOROLOGICAL DATA

The following tables give information on climatic conditions in a few cocoa-growing countries. Malaya has, so far, only grown a small amount of cocoa, but climatically it is suited to the crop.

Even at Tafo in the Gold Coast, St. Augustine in Trinidad, and Bahia in Brazil, all of which are reckoned to have an adequate average rainfall, cocoa suffers from drought in seasons when the rainfall has been abnormally low. In New Britain, with its relatively high rainfall, the trees—especially young ones—planted on a porous volcanic soil have had a setback on the rare occasions when the rainfall has been below normal.

The meteorological data are derived from the following sources:

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ST. AUGUSTINE, Trinidad: I.C.T.A. (from information given to students).
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MALAYA: *Report on suitability for cocoa-growing of the territories of Malaya, Sarawak and British North Borneo*, by D. Gillett. (Private Report to Cadbury Brothers Ltd., 1948.)
RABAUL, New Britain: *The Growing of Cacao in Papua and New Guinea* (Appendix 7), by D. H. Urquhart and R. E. P. Dwyer (Cadbury Brothers Ltd., 1951).
MULINU'U, Western Samoa: *Cocoa Growing in Western Samoa* (Appendix 1), by D. H. Urquhart (Technical Paper No. 39, South Pacific Commission).

The graph is adapted from *Le Cacaoyer à Tafo* (*Gold Coast*), by L. Poncin (Brussels, 1950).

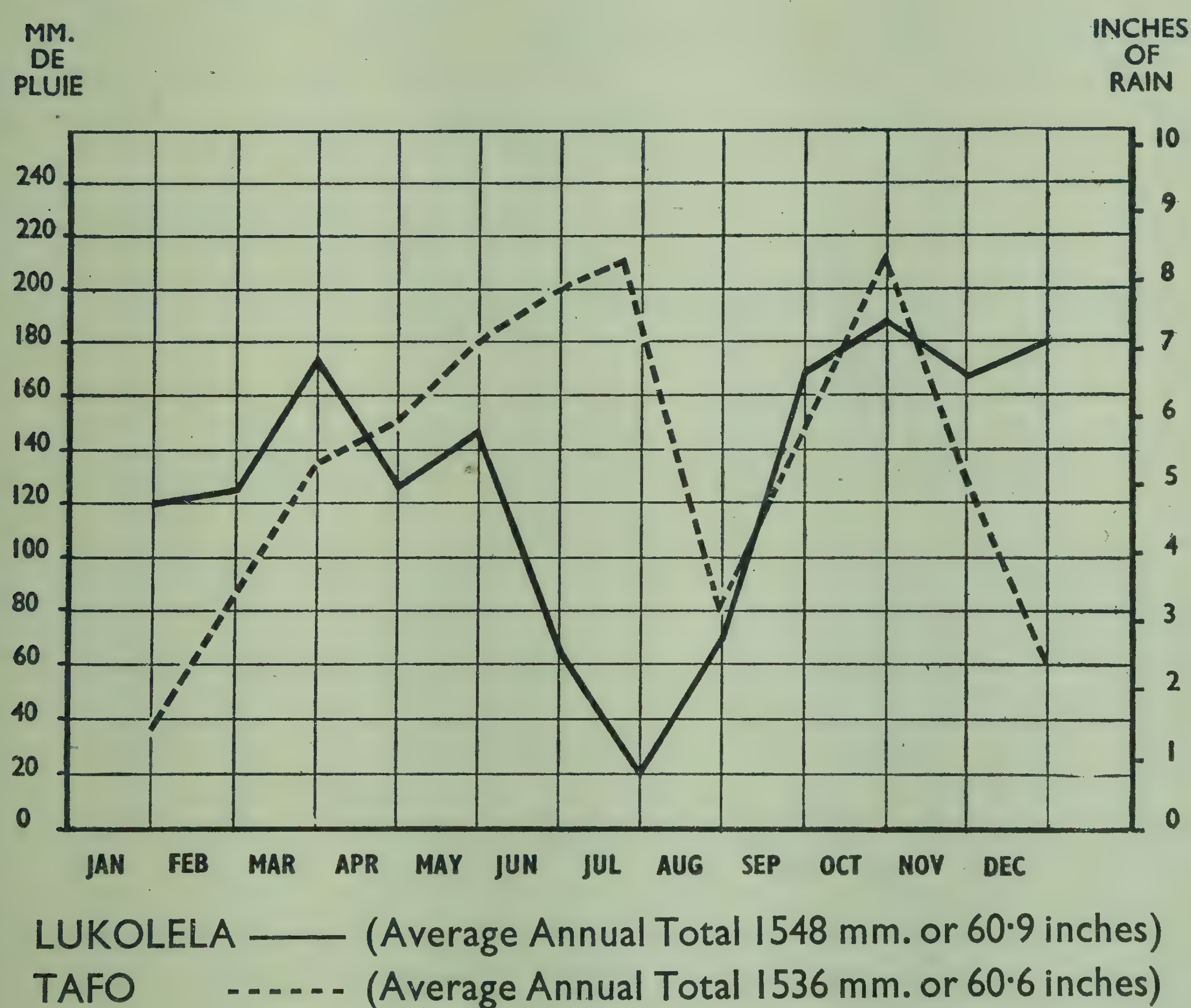

FIG. 1

AVERAGE MONTHLY RAINFALL (1938–47) AT TAFO, GOLD COAST AND LUKOLELA, BELGIAN CONGO

METEOROLOGICAL DATA OF SOME COCOA-GROWING COUNTRIES

1. TAFO, GOLD COAST (15-year period, 1938–52)

Month	*Shade Temp. Mean Max.* (*degrees Fahr.*)	*Mean Min.*	*Mean Rel. Humid. 9 a.m.* (%)	*3 p.m.* (%)	*Mean Rainfall* (*inches*)	*Average No. of Wet Days*
January ..	91·4	59·1	85·9	54·1	1·56	3·4
February ..	93·7	61·2	83·7	51·3	3·63	7·3
March ..	93·5	65·8	81·6	54·7	6·09	11·6
April ..	93·7	66·1	80·5	57·9	5·80	11·2
May ..	92·1	66·6	81·7	62·3	7·07	13·4
June ..	89·3	66·1	84·7	67·9	8·33	18·4
July ..	86·8	66·2	86·0	68·9	5·53	13·4
August ..	86·4	65·0	85·9	61·3	2·79	12·8
September ..	88·0	66·6	85·1	70·6	6·23	13·9
October ..	89·8	66·3	83·1	69·8	8·65	18·0
November ..	90·5	65·0	81·8	65·4	5·08	11·0
December	90·6	62·7	84·2	61·4	2·44	5·0
			Total for year	..	63·20	139·4

2. ST. AUGUSTINE, TRINIDAD (21-year period, 1929–49)

	Temperature Mean Max. (*degrees Fahr.*)	*Mean Min.*	*Sunshine Dly. Av.* (*Hrs.*)	*Humidity Mean Min.* (%)	*Mean Rainfall* (*inches*)	*Average No. of Wet Days*
Dry Season:						
January ..	84·0	68·0	7·6	57·0	2·8	16·0
February ..	85·0	67·0	8·2	52·0	1·3	11·0
March ..	86·0	68·0	8·0	51·0	1·3	21·0
April ..	87·0	71·0	8·1	52·0	1·9	10·0
May ..	88·0	72·0	7·8	57·0	5·0	16·0
Wet Season:						
June ..	86·0	72·0	6·7	63·0	8·6	22·0
July ..	86·0	72·0	7·2	63·0	8·6	23·0
August ..	87·0	71·0	6·9	63·0	9·8	23·0
September ..	87·0	72·0	6·5	62·0	7·9	19·0
October ..	87·0	72·0	7·0	62·0	6·4	17·0
November ..	86·0	71·0	7·0	63·0	7·8	28·0
December ..	85·0	70·0	7·1	62·0	6·4	20·0
			Total for year	..	67·8	226·0

3. URUÇUCA, BAHIA

	1937 Temperature Mean	Max. Shade (degrees Fahr.)	Min. Shade	Ave. Hum. (%)	1941–50 Rainfall (in.)	No. of Wet Days
January ..	77·5	92·0	64·4	84·6	4·25	17
February ..	77·0	91·6	66·2	87·1	4·52	16
March ..	77·7	94·0	67·5	84·2	8·32	22
April ..	75·2	94·3	64·4	87·9	9·95	22
May ..	73·4	95·4	57·6	85·3	4·37	18
June ..	70·7	93·2	59·4	88·4	10·22	22
July ..	69·4	88·0	58·3	88·0	5·50	21
August ..	70·3	89·2	55·4	85·8	4·61	20
September ..	70·3	89·6	53·6	86·0	4·14	18
October ..	74·8	93·2	60·8	85·2	5·87	18
November ..	76·8	93·0	61·9	88·6	8·69	20
December ..	77·2	94·3	63·5	85·2	6·80	19
Total for year ..					77·24	233

4. MALAYA (Rainfall)

	Kuala Lumpur	Kuala Trengganu
No. of years recorded:	58	12
	(average in inches)	
January ..	6·68	11·77
February	6·18	7·51
March ..	9·20	10·72
April ..	10·73	5·35
May ..	8·48	5·21
June ..	5·07	5·36
July ..	4·13	5·34
August ..	6·31	5·61
September	7·33	6·31
October ..	11·09	16·22
November	10·19	31·98
December	9·53	23·40
Total for year ..	94·92	134·77

5. RABAUL, NEW BRITAIN (25 years)

	Temperature Mean Max. (degrees Fahr.)	Temperature Mean Min.	Temperature Average Monthly	Rel. Humidity Mean Max. (%)	Rel. Humidity Mean Min. (%)	Mean Rainfall (inches)	Average No. of Wet Days
January ..	90·7	73·5	82·1	79·0	72·0	14·13	20·8
February	88·9	73·8	81·3	79·0	72·0	10·44	13·1
March ..	88·4	73·4	80·9	83·0	75·0	9·42	19·5
April ..	89·3	74·0	81·6	83·0	72·0	9·80	18·0
May ..	88·9	73·9	81·4	79·0	72·0	5·17	13·3
June ..	88·5	73·8	81·1	79·0	72·0	3·62	12·7
July ..	88·7	72·8	80·7	87·0	72·0	5·59	14·7
August ..	88·8	73·5	81·1	79·0	72·0	4·40	14·8
September	89·8	73·6	81·7	75·0	72·0	3·65	12·5
October ..	90·3	73·6	81·9	75·0	68·0	5·25	12·7
November	90·8	74·1	82·4	76·0	76·0	6·30	15·7
December	90·4	73·4	81·9	75·0	72·0	10·19	18·3
			Total for year ..		..	87·96	186·1

6. MULINU'U, WESTERN SAMOA

Month	Temperature Mean Monthly (degrees Fahr.) (a)	Temperature Mean Max.	Temperature Mean Min.	Avge. Sun-shine (hours)	Rel. Humidity (%) (a)	Mean Rainfall (inches)	Avge. no. of Wet Days	Cloudi-ness (8ths)	Wind Speed (mph)
January ..	79·51	85·1	75·2	178·3	84·7	17·54	23	5·4	5·8
February ..	79·50	85·3	75·2	163·0	84·8	14·94	20	5·2	5·9
March ..	79·53	85·6	75·0	199·8	84·8	13·67	21	4·9	5·2
April ..	79·43	85·7	74·8	211·5	84·5	9·77	18	4·6	5·3
May ..	78·98	85·3	74·1	222·0	83·9	6·81	15	4·2	6·0
June ..	78·37	84·5	73·0	224·1	82·3	5·28	12	3·8	7·7
July ..	77·77	83·9	72·5	245·2	81·7	3·52	12	3·6	8·1
August ..	78·25	84·1	72·8	249·7	80·4	3·77	12	3·6	9·4
September	78·57	84·4	73·4	235·5	81·2	5·45	13	4·0	8·6
October ..	79·03	84·8	74·0	229·2	81·5	7·11	15	4·3	8·1
November	79·12	85·1	73·1	203·1	82·8	10·26	19	4·8	6·4
December	79·48	85·1	74·8	181·9	83·5	14·77	21	5·1	6·4
Mean or Total:									
Year ..	78·96	84·9	74·0	2,543·3	83·0	112·89	201	4·5	6·9
Wet Season	79·40	85·2	74·6	726·3	84·0	57·51	83	5·1	6·1
Dry Season	78·24	84·2	72·9	954·5	81·4	18·02	49	3·8	8·5
No. of years	62	61	61	27	29	62	61	56	19

(*a*) 24-hourly values.

Chapter IV

COCOA SOILS*

Root-room—Sands—Clay-loams—Soil-aggregate Cementing Agents—Soil-crumb—Forest Soils—Soil Depth—Classifying Soils on a Root-room basis—Planting Distance—Effects of Forest-felling—Functions of Shade—Soil Erosion—Rehabilitation of Worn-out Cocoa Lands—Mulching and Mulches—Effects of Mulching: Use of Fertilizers—Root-systems.

ROOT-ROOM

COCOA soils may best be considered from the point of view of root-room; that is, the volume of soil which is fully occupied by roots when the tree has reached maturity. To be completely effective, the rooting volume of a soil must contain at all times sufficient water, air, and available nutrients to meet the requirements of the growing tree and of the developing crop. In order that a soil may be capable of satisfying these requirements, it must possess a highly porous structure and a relatively large content of clay, and it must not hinder root penetration.

SANDS

Certain sandy soils possess all these desirable features, so long as their particle diameter is sufficiently large to provide pores of a size big enough to permit rapid drainage of water, free ventilation of air, and easy root penetration, assuming always that the prevailing rainfall is high enough and the showers sufficiently frequent to keep the sand continuously moistened.

Free-draining sands have a minimum particle diameter of about 0·5 mm. which corresponds to a minimum pore-size of about 0·2 mm. Root-tips range in size from 0·5 to 0·1 mm., so that free-draining sand will not impose undue restrictions on root growth. The pore-space volume of sand at closest ("cannon-ball") packing is 24·5 per cent of its total volume. This may be regarded as the minimum total pore-space for a freely-drained and well-aerated sand having particle size above 0·5 mm. diameter.

* By Professor F. Hardy, C.B.E.

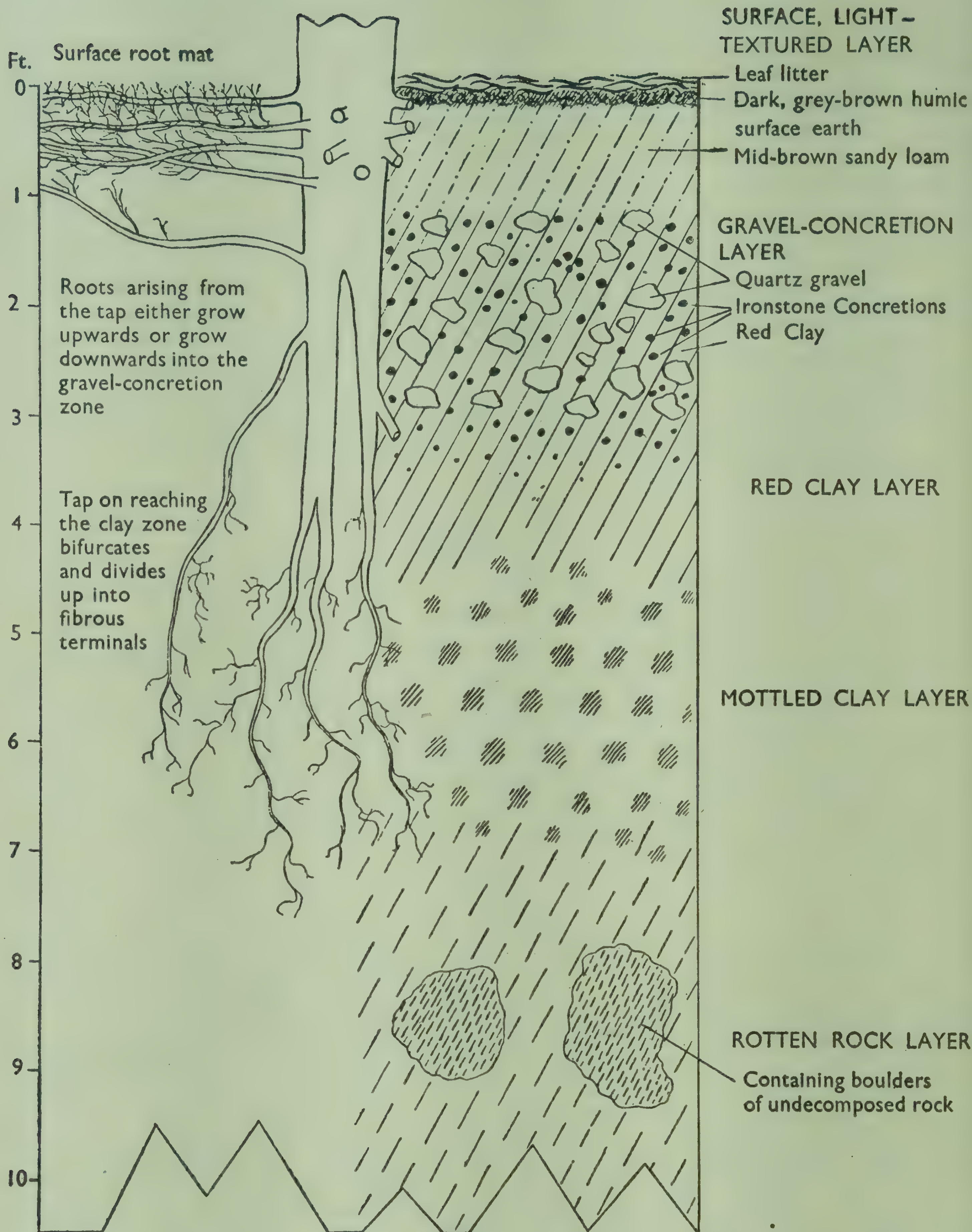

FIG. 2

DIAGRAMMATIC PROFILE OF THE RED WELL-DRAINED SOIL OF THE UPLANDS IN THE GOLD COAST SHOWING HOW THE TYPICAL COCOA ROOT SYSTEM EXPLOITS THE VARIOUS LAYERS

When wetted and drained, a mass of sand contains its water solely as films around the solid particles and as wedges between them, leaving most of the pore-space open for drainage and ventilation. The plant roots obtain their water from these wedges and films which, however, must be continually replenished by rain, otherwise the sand soon dries out. Hence, unless the rainfall is suitably distributed, sandy soils are useless for cocoa-growing, quite apart from the fact that their component grains may consist mainly of inert quartz which, of course, is entirely incapable of providing plant nutrients.

CLAY-LOAMS

Better than sands for cocoa-growing are clay-loams, consisting of stable aggregates of fine sand, silt, and clay, which behave like coarse sand grains and yet have the important additional advantage of a much greater moisture-holding capacity because of the well-known property of clay for absorbing water. Such soils do not depend as much as sands on the vagaries of the rainfall, and because of their clay component they are also more likely than sand to contain nutrient substances.

The total pore-space of a well-aggregated clay-loam may be as high as 66 per cent (corresponding to an apparent specific gravity of about 0·90), of which about one-half (33 per cent) will be filled up with water when the soil is wetted, owing to absorption by the clay component which swells up to this extent when moistened, leaving the other half of the total pore-space (33 per cent) quite empty. The absorbed water is sometimes referred to as "capillary water" on the assumption that clay contains a large number of very minute capillaries that can hold water strongly against the pull of gravity though they cannot hold it with sufficient force to resist completely the pull exerted by plant roots. The rest of the pore-space (33 per cent) in a moistened aggregated clay-loam is called "non-capillary" pore-space. It comprises pores large enough to allow rapid removal of water. The non-capillary pores are full of air when a clay-loam is completely drained. They comprise the main ventilating system of the soil, and they are large enough also to allow roots to grow freely through them. Among the naturally occurring larger non-capillary pore-spaces are old root-traces, worm-holes, insect-cavities, termite-channels, cracks, and fissures. These all help to drain the soil after rain and to allow air to circulate freely within it.

SOIL-AGGREGATE CEMENTING AGENTS

Since the best cocoa soils are undoubtedly aggregate-structure clay-loams it is important to know what particular agents are responsible for the formation and the stabilization of soil aggregates. Recent research has shown, first, that aggregates are formed by the alternate swelling and shrinking caused by repeated wetting and drying of a soil, and secondly, that the chief agent which cements, fixes, and stabilizes the aggregates is the sticky mucilage produced by certain bacteria and blue-green algae that live in decomposing organic matter.

Thus, aggregate structure is best developed where humus is abundant. Doubtless other agents besides mucilage are concerned in the cementation and stabilization of soil structure; for example, hydrous ferric oxide and calcium carbonate. Ferric oxide is mainly responsible for red and brown colours in aggregated soils, and calcium carbonate (when combined with humus) for the jet-black colour of the highly aggregated soils known as Rendzina or "humus-carbonate" soils which develop over marlstones and calcareous clays.

SOIL-CRUMB

The commonest kind of aggregate that is stabilized by mucilage derived from soil organic matter is usually rounded, loose, and rough-surfaced. It is commonly termed "soil-crumb." The size of crumb aggregates ranges from over 5 mm. to less than 0·2 mm. An average sample somewhat resembles coarse bread crumb.

Soil-crumb generally contains over 5 per cent of humus, and sometimes as much as 20 per cent, as well as a correspondingly high content of nitrogen. The ratio of its content of carbon to that of nitrogen (the "carbon-nitrogen—C/N—ratio") is mostly well over 12, which, to the soil chemist, implies that its organic matter component is not completely broken down or "humified" so that it is capable of supporting a large population of micro-organisms, such as soil bacteria. In addition to a high content of nitrogen, crumb usually contains relatively large amounts of available phosphate and available potash.

Soil-crumb not only possesses ideal physical properties, but it also serves as a rich storehouse of plant nutrients. It may be regarded as one of the most important and valuable natural products in the world.

FOREST SOILS

The thickness of the crumb layer varies greatly in cocoa soils, depending on various circumstances, including the past history of the soil. Natural forest soils, which are most generally the immediate predecessors of cocoa soils, may first be considered.

The kind of forest that develops under the particular climate that is suitable for the growth of cocoa is known as "Evergreen Seasonal Forest." It generally consists of from three to five distinct storeys. The uppermost storey comprises a relatively small number of "emergents," which are exceptionally large trees that tower above all the others, often to a height of 150 feet. The storeys below form more continuous but separate canopies of different heights. The lowest canopy is the undergrowth. Lianes or creepers are abundant. Such a forest sheds its leaves continuously and the amount of ground litter that collects may be large. The litter forms a thick layer over the forest floor. Among the component trees of the forest may be several species of *Leguminosae* which enrich the soil with nitrogen taken up by bacteria living in nodules on their roots.

Where there is an underlying soil of suitable texture (mechanical composition), such as clay-loam, the products of decomposition of the forest litter are carried down into the mineral soil below by various soil animals, notably worms, and in due course soil-crumb is formed. Where the parent rock and the climate are suitable, and where undulating topography permits free external drainage, maximum development of forest vegetation occurs and, given sufficient time, the thickness of the final crumb layer may be considerable. As it is extremely well aerated and protected from drying-out by the cover of litter over it, crumb soil is a most favourable medium for root-growth and in forest soils is generally fully occupied by roots. The crumb-soil roots are fine and fibrous and lie in close contact with the decomposing litter from which they absorb nutrients directly or through the agency of threads of fungus (mycorrhiza) which are commonly associated with forest tree roots. The fibrous superficial roots seem to have another function besides "feeding" on the rotting litter, in that they may manufacture small quantities of highly active growth-promoting substances which greatly help in the development of trees.

The transition between true soil-crumb—with its dense mass of fibrous roots—and the soil below is generally gradual, the structure within the rest of the humic soil-layer being coarser and more "nutty" or "cloddy," or even "blocky."

As a good example of a well-structured soil originally developed

under Evergreen Seasonal Forest, may be cited the so-called "Chocolate Soil" of Trinidad. This is derived from an uncommon rock known to geologists as glauconitic calcareous sandstone, which is exposed in certain places in the Central Range. The crumb-layer of the Chocolate Soil is from one to three inches thick, or even more, and humic penetration goes down to twelve to thirty-six inches or more. The subsoil shows a well-marked nut to small clod structure, within which roots readily ramify. A similar deep soil, derived from an igneous rock called granodiorite, occurs in the Gold Coast where it has been extensively used for cocoa-growing.

By contrast, where the parent rock is not suitable to the maximum development of forest vegetation because of its mineralogical and chemical composition, and/or its compact or "massive" physical constitution which impedes downward drainage, the thickness of the crumb layer may be relatively small or even altogether absent.

In the Northern Plain in Trinidad, certain alluvial silty-clays are widespread and were once occupied by under-developed Evergreen Seasonal Forest. These clays have given rise to shallow acidic soils with high "perched" water-tables, in which crumb-soil is only sparsely represented. The hard soil immediately below the crumb is scarcely cracked, and humic penetration is usually less than six inches. These soils, when freshly cut out of the forest, supported good stands of cocoa, but they rapidly deteriorated after about twenty years, until now they can only be regarded as marginal for cocoa.

In the Gold Coast, cocoa soils developed over certain phyllites (Birrimian), clay-shales (Voltaian and Buem), and quartz-schists (Akwapimian), have also proved to be unprofitable for similar reasons.

SOIL DEPTH

It is evident from a consideration of these examples that the depth to which different soils develop an aggregate structure stabilized by humus products or by other cementing materials may vary greatly. It depends partly on the climate, which chiefly decides the kind of forest that arises, and partly on the kind of parent rock, which determines the luxuriance of the forest and the amount of litter that accumulates, as well as the ease with which humus becomes incorporated into the mineral soil. Thus, the amount of root-room (defined at the outset as the volume of the soil whose physical properties are favourable to the maximum development of roots, mainly because of its ideal water and air relations) may range in

depth from almost zero to as much as three or four feet. At the one extreme, where there is little or no humic penetration, roots can only grow and ramify upon and over the surface, being unable to force their way into the compact unstructured soil below, except down the sparse cracks that may be formed as the soil dries out. At the other extreme, where organic penetration is deep and the humic soil possesses throughout an open porous structure, roots are able to ramify profusely within the whole soil-mass. Between these extremes most normal productive soils occur.

CLASSIFYING SOILS ON A ROOT-ROOM BASIS

The root-room concept provides a reasonable method of classifying soils on a physical basis. If combined with some means of expressing nutrient status, based for example on chemical analysis, a complete practical scheme of soil classification might be elaborated which in the simplest form would comprise eight categories, namely: (i) deep rich sands, (ii) deep poor sands, (iii) shallow rich sands, (iv) shallow poor sands, (v) deep rich clays, (vi) deep poor clays, (vii) shallow rich clays, and (viii) shallow poor clays. This scheme has been effectively applied to Trinidad cocoa soils.

PLANTING DISTANCE

One important advantage of knowing the root-room of a given soil is that it provides a means of determining planting distance, which clearly should be greater for shallow soils having small root-room than for deep soils having large root-room. This presupposes that close planting will not cause undue interference between adjacent tree canopies, but if it occurs it may easily be adjusted by careful pruning.

EFFECTS OF FOREST-FELLING

When forest is felled for the establishment of cocoa plantations, great care should be taken not to expose the bare soil to the direct beating action of rain nor to direct sunlight. This may be achieved by leaving some of the largest trees to form a "shelter wood," or by planting "ground shade," consisting of appropriate kinds of banana, tannias (cocoyams), cassava, or similar rapidly growing leafy plants, or small shade-trees such as *Gliricidia*, *Cassia*, *Tephrosia*, *Leucaena*, which are leguminous plants, or non-leguminous weed species having similar habit. More permanent shade such as immortelle (*Ery-*

thrina spp.) may be planted along with the cocoa at suitable spacing. If the cocoa crop is subsequently planted through this ground-shade, and both cocoa and shade (including the permanent shade) are carefully tended, the transition from forest to cocoa need not be fraught with danger to the important crumb layer of the soil.

Failure to observe these precautions may result in the rapid destruction and loss of the crumb and of some of the well-structured highly humic soil below. Within a few weeks, the whole of the rich top layer of structured humic soil may have disappeared under the combined action of beating rain and strong sunlight, and the forest accumulations of centuries will have been squandered and wasted.

Experimental measurements made in the Arena Forest Reserve, Trinidad, have shown that the clear-felling of the Evergreen Seasonal Forest increases the evaporating capacity of the air four and a half times, mainly because it lets in sunlight and wind. The amount of radiant energy reaching the forest floor is increased twelve times by felling, and the range of shade temperature is doubled. The moisture content of the top six inches of soil (a loose sand) is reduced during the dry season by two-thirds. The organic matter content of the soil in all layers down to twenty-four inches is diminished considerably through enhanced oxidation and the C/N ratio is appreciably lowered. Marked deterioration occurs within eight weeks after the felling. Grasses and agricultural weeds rapidly invade the exposed soil and natural forest regeneration is consequently greatly retarded.

At first, a large increase in the amount of leaf litter follows the death of the fallen trees. Branches and trunks contribute to the organic detritus in the form of fungus-rotted wood, and frass produced by burrowing insects. When burning accompanies the felling, the resulting plant-ash temporarily raises the mineral content of the soil and greatly reduces its acidity because it contains alkalis. Burning may also lower the soil's content of nitrogen. These results may alter the kinds of micro-organisms that inhabit the soil, fungi being gradually replaced by bacteria.

FUNCTIONS OF SHADE

Shade trees and ground-shade shrubs contribute considerable amounts of nitrogen to the soil by their root-nodules, leaves, twigs, and flowers.

Root-nodules of immortelle trees in Trinidad contain over 4 per cent of nitrogen, leaves contain 2 to 3 per cent, and flowers 3 to 6 per cent. The amount of nitrogen contributed by the fall of flowers alone in one year is 20 lb. per acre. Cocoa beans, 500 lb. per acre,

remove about 12 lb. of nitrogen per acre, so that there is a net gain of 7·5 lb., equivalent to nearly 40 lb. of ammonium sulphate fertilizer per acre.

The idea that the only functions of shade trees are to diminish the intensity of incident light and to protect the cocoa trees from excessive evaporation caused by moving air may not be the whole truth. The name once used for the immortelle tree in Trinidad by the old Spanish cocoa planters was *madre de cacao* (mother of cocoa), suggesting nourishment. Possibly the contribution of nitrogen to the soil by the deliberate planting of leguminous trees among the cocoa, either as shelter or shade, may be considerable, judging by the fact that old shaded cocoa in Trinidad does not respond to nitrogenous fertilizers, whereas unshaded cocoa, both in Trinidad and in Grenada, responds markedly.

SOIL EROSION

Sheet erosion, caused mainly by flooding, successively removes leaf-litter, crumb-soil, and some humic topsoil, and so progressively exposes layers of diminishing organic matter content and falling C/N ratio. Where the soil is shallow and the cocoa's root system (including horizontal woody roots) is superficial, sheet erosion may severely damage the tree by dissecting out the roots and removing or injuring many of the branched terminals and active "feeding roots." Unless the soil losses are rapidly made good by the formation of new soil, the rooting volume becomes restricted by the removal of the best-structured and the most highly-aerated upper portion. At the same time, the supply of nutrients is greatly decreased. Diminution of the amount of crumb-soil and of the next few inches of highly humic soil below it is probably the main cause of soil deterioration that follows forest-felling and exposure of the land to rain, wind, and sun.

By means of simple pot-tests—growing a test-plant, such as tomato, in samples taken from each layer—the relative fertility of the crumb layer and of the layers that occur successively below it may be compared. The test is well worth making since the results are usually most spectacular. At the end of the trial, the crumb-soil will generally be found to be still well-aggregated, highly permeable, and completely filled up with roots, whereas the sub-soil (being less stable) may have lost its open structure, and "run together" somewhat, and it may be less fully occupied by roots.

Loss of litter and soil-crumb and of some of the humic soil below brings the less fertile soil to the surface. The possibility of utilizing

this for growing cocoa, or of re-establishing from it a highly fertile soil, depends largely on the mineralogical composition of the parent rock from which the initial soil was generated. If this is rich in nutrient-bearing minerals, as is the glauconitic sandstone of Trinidad and certain of the more basic igneous rocks of West Africa, regeneration is usually rapid, once second-growth vegetation has become established or the missing nitrogen is added as fertilizer or manure. If, on the other hand, the parent rock contains only a small proportion of nutrient minerals, regeneration of a fertile soil by natural processes is long delayed, unless complete fertilizers or manures are skilfully used. Only detailed soil surveys can determine the potentialities of eroded or worn-out soils for rejuvenation under proper treatment, and the extent and distribution of soil types having different potentialities.

REHABILITATION OF WORN-OUT COCOA LANDS

The rehabilitation of old cocoa fields is likely to be more successful if it takes the form of partial replacement rather than complete removal of the old cocoa by clear-felling before the replanting. This conclusion follows from the principle, mentioned in an earlier paragraph, of the "shelter-wood" system, so widely used at the present day by foresters in producing timber plantations from natural tropical forest by selective thinning. Protection of the soil, the maintenance of the right atmospheric conditions near its surface, and the conservation of the crumb-soil layer with its attendant cover of decomposing litter, should be the essential aims in attempting to rehabilitate old cocoa lands. Where soil erosion and soil deterioration have gone on to such an extent that yields have drastically declined, the process of building up a fresh crumb layer and of raising the organic status of the top soil may prove to be difficult, lengthy, and costly. The process, in effect, is an attempt to reinstate, within the cocoa plantation, the original forest soil and the characteristic atmospheric conditions of the forest. The methods available are limited, because they must not only be efficacious, but they must also be economical and cheap.

MULCHING AND MULCHES

A great deal can be done to restore the soil by the use of mulches where these are readily obtainable. Among the naturally moist mulching materials that are suitable are cut-bush and grass, such as grow in waste places and waysides, or may be specially grown for

the purpose (possibly with the use of fertilizers) in abandoned fields, on barren hill-slopes, and rocky places unsuited to the profitable cultivation of crops.

The actual species of bush and grass that might be used for mulch will naturally depend on the suitability of the particular plants which grow in the vicinity or which can easily be introduced from outside. In Trinidad, any of the species of shrubs mentioned earlier as suitable for ground-shade might also be suitable for mulching, particularly *Gliricidia* which sets roots easily, grows rapidly, and produces abundant shoots which, when lopped off, provide good mulching material in considerable quantity. Strips of land and paths between cocoa fields may be planted up with suitable mulch-bushes or grass, or the plantation may be replanted in blocks to allow mulch bushes or grass to be grown around or between the blocks.

Among the dry vegetable waste-products that might be used as mulch are sawdust, wood-shavings, straw, stover, and sugar-cane bagasse. Where these may be obtained readily and cheaply, they are highly beneficial when applied in layers, say, three to six inches thick and allowed to rot down, appropriate and timely replenishment being made so as to maintain a constant covering. Pen manure or other organic manures, when available and cheap, may also be used, not only as mulch, but also as nutrient suppliers.

EFFECTS OF MULCHING: USE OF FERTILIZERS

The use of mulches in cocoa plantations is mainly to provide a suitable medium for the development of the cocoa root-system by maintaining a highly porous layer which is well-aerated and highly retentive of water. In addition, mulches supply variable but often considerable amounts of plant nutrients, namely nitrogen, phosphate, and potassium, as well as other essential elements, including trace elements such as iron, manganese, magnesium, zinc, and copper. Moreover, these nutrients are liberated slowly but continuously by mulches which, in contrast with fertilizers, supply large quantities of nutrients at one time. When a large and healthy cocoa root-system has been established, further benefit may be obtained and the natural supply of leaf litter greatly increased by judicious use of fertilizers, such as ammonium sulphate, superphosphate, and potassium sulphate. Care must be taken, however, to use these fertilizers in balanced proportions. In order to achieve this, the help of the analytical chemist should be sought for the purpose of checking nutrient uptake by periodic leaf analysis.

By means of mulches and fertilizers skilfully used, eroded and

deteriorated cocoa soils may be rapidly rejuvenated and the growth and vigour of the trees greatly increased so that the normal cycle of nutrient circulation, involving the accumulation and decomposition of leaf litter, is soon reinstated. Eventually, the amount of the mulch dressings might deliberately be diminished and the quantities of fertilizers reduced and adjusted, so as merely to make good the losses brought about by the removal of the crop, thus materially reducing the cost of mulching, which is an expensive operation.

Cocoa beans in Trinidad contain approximately 2·4 per cent of nitrogen (N), 1·2 per cent of phosphate (P_2O_5), and 1·9 per cent of potash (K_2O). An annual crop of 500 lb. of beans per acre therefore removes from the soil about 12 lb. of N, 6 lb. P_2O_5, and 9·5 lb. K_2O, equivalent to a dressing of 60 lb. of ammonium sulphate, 33 lb. of superphosphate, and 19 lb. of potassium sulphate per acre, or about 6 oz. of mixed fertilizer per tree per year.

ROOT SYSTEMS

Root systems characterized by tap-root domination are capable of fully and rapidly utilizing rich deep soils with ample rooting volume. The young vigorous thin tap-root which develops from the radicle of the germinating cocoa beans, or from the base of a chupon or sucker, is able to grow between the soil structure units or down a convenient small crack, until it reaches a water-table or penetrates a great distance into permeable moist subsoil. Once established, it rapidly thickens into a conical-shaped object which puts out whorls and tiers of horizontal secondary woody roots which, with their ramifying branches, explore the whole of the soil volume and abstract large quantities of available water therefrom. At the same time, surface-feeding roots grow out from the base of the young stem and occupy the crumb layer and the decomposing under-part of the litter, from which they obtain an abundant supply of nutrients.

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Chapter V

THE COCOA PLANTATION (1)

ESTABLISHMENT AND MAINTENANCE

I. PRELIMINARY PREPARATION

Overall Considerations—Choice of Site—Soil Assessment—Communications, Water Supply, etc.—Planting Material—Preliminary Operations—Subsequent Operations.

OVERALL CONSIDERATIONS

THIS chapter describes in their sequence the operations entailed in laying-out a plantation and in its subsequent care. Some of the points are discussed at greater length in other chapters.

No description of plantation practice could cover all the various methods employed in the tropical countries where cocoa is grown. Variations are sometimes dictated by climate and soil, by the type of labour available, and by traditions and fashions evolved in each country.

While actual practice varies, the basic principles which make for the profitable growing of cocoa are similar. The planter who would make a success of the work in one part of the world would be most likely to make a success of it in another.

CHOICE OF SITE

The choice of site for a plantation will be dictated by certain basic considerations.

Although in the past, sound judgment based on experience guided the more successful planters in their selection of suitable land for cocoa, many plantations of cocoa and other tropical crops have been sited on unsuitable soils. The assumption that soils which carry dense forest must necessarily be productive if the forest is replaced by a plantation has led to much disappointment. It may also be misleading to judge the quality of the soil by its cover in the absence of an intimate knowledge of the type of flora that indicates fertility.

The African peasant built up the greatest cocoa-growing industry in the world without the aid of scientific knowledge, as we understand the term. He achieved success by growing cocoa widely; where it grew well, he grew more of it. In course of time wisdom born of experience prompted him to test the suitability of the soil for cocoa by planting a few trees in advance of any general planting, and he thus acquired a considerable degree of judgment.

This method of trial and error was sufficient for a peasant community at a certain stage in its progress, but for the prospective planter at the present time it is not a practical way of choosing land for cocoa.

SOIL ASSESSMENT

Where such services are available, the assistance of the Department of Agriculture or Research Institute, with staff trained in the study of soils, or the advice of experienced local planters, will be sought. In the absence of these, large companies contemplating development in unsurveyed territory would normally import the necessary skill for their own guidance. In assessing the suitability of a new area, the condition of growth of certain forest plants or farming crops, such as bananas, plantains, and tannias, the luxuriant growth of which is accepted as indicating good conditions for cocoa, would be noted. Similarly, the presence of certain trees which are known to thrive on poor soils or which are indicative of waterlogged or other conditions unsuitable for cocoa would be observed. In the absence of professional skill or guidance on the spot, anyone with a working knowledge of soils can gain a great deal of information by the use of a soil auger. An ordinary carpenter's auger, about 1½ inches in diameter, can be converted for the purpose by having the stem lengthened to about 4½ feet. It can probe the ground and bring up enough of the soil to give an indication of its constituents, the depths of its various layers of heavy or light soils, its general texture and its capacity for drainage or retention of moisture. Soils in the tropics are liable to vary widely within a small area, and a simple survey with a soil auger, used up and down the site, will often provide more useful information than any other form of investigation. A preliminary assessment of the acidity and the presence or absence of potash, etc., can be made by the use of soil examination kits. Such assessment should be supplemented by a report on soil samples by an appropriate authority.

Soils which will sustain the growth of the cocoa tree must contain enough clay to enable them to retain sufficient moisture to

assure the growth of the plant through dry periods, but it must not be so heavy as to impede drainage or the circulation of moisture and air.

The extent to which organic matter or humus is present in the surface layer may decide at the outset whether cocoa can or cannot be established. Organic matter helps to keep a clay soil friable and makes a sandy soil more retentive of moisture. In addition to improving the physical character of the soil, organic matter is the medium from which the feeding roots will draw most of the plant's nourishment. The care with which the accumulated organic matter is conserved when opening up land for planting, and the skill with which it is maintained and augmented throughout the life of the plantation will greatly influence the productivity of the trees.

COMMUNICATIONS, WATER SUPPLY, ETC.

Accessibility by road or water is important as means of communication have an important bearing on costs.

Water supplies must be studied from the point of view of the needs of the labourers and also of the nurseries.

The number of labourers and the amount of accommodation required for them, and also the size and equipment of the buildings necessary to carry on plantation operations, will be calculated in relation to the size of the venture planned.

Where circumstances permit, it is cheaper in the long run to erect the more expensive permanent buildings at an early stage, rather than to put up temporary buildings which are later to be replaced by permanent structures. If temporary buildings are made they should be such that they will last ten years at least without requiring major repairs. The chief accommodation required will be housing for labour, overseers, and owner or manager, and houses for fermenting and storage.

A number of roads will be required in the early stages, but a more complete road system will be developed gradually. A cambered road with offsets leading to deep holes to take the run-off is much better than one with deep ditches on both sides. Nowadays, even the smaller tractors can be fitted with light bulldozers or road graders, which reduce the costs of earth-moving, road-making and maintenance.

There will be expenditure on basic equipment in the form of axes, saws, machetes, shovels, crowbars, and files. The number of lorries and tractors required will depend on the size of the venture and the availability of local transport and machinery for hire.

PLANTING-MATERIAL

The source of cocoa planting-material is a matter which will be investigated early in the proceedings, as its type will have a considerable influence on the financial returns from the plantation.

Planting-material is easily transported in the form of seed, but, with a few exceptions, uniform results cannot be expected from selected cocoa seed at the present time. Vegetatively propagated cocoa material gives consistent results.

Included in the plantation requirements will be seed for temporary and permanent shade. If the plantation is isolated, provision may also have to be made for seed and planting-material for food-crops to supply the needs of labour.

PRELIMINARY OPERATIONS

The preliminary operations involved in making a cocoa plantation will vary to some extent from country to country, and with the condition of the land to be planted, depending on whether it is in high forest or secondary bush or has been recently planted with another crop.

High and secondary forest will have to be selectively thinned or cleared. Where the land is already cleared, provision for ground cover and shade must be made at an early stage.

Nurseries will be required, whether the method of planting is by seedlings first grown in the nursery and then planted in the field, or by direct planting of seed. In the latter case nursery plants will be required to replace those which have weakened or died during the first two years.

Nurseries to provide permanent shade trees and, perhaps, temporary shade trees will also be required.

Subsequent operations, such as the removal of chupons or suckers, pruning or shaping of trees, and weeding, will be necessary in most countries. Control of temporary and permanent shade trees will depend on how much shade is desired. Cultivation to a greater or lesser extent, especially in the early years, is common in many countries, but manuring is less common. Drainage may require attention.

The need for measures of disease control at various stages differs from country to country; in some they may be necessary at all stages, and in others the need may be negligible.

II. PREPARATION OF THE LAND

Clearing: Complete Felling and Burning; Selective Thinning; Partial Clearing—Sale of Timber—Sequence of Operations —Mechanization in Felling—Planting in old Plantation Land or Land without Forest—Prevention of Erosion—Bench-terracing—Drainage.

Where the land to be planted is under forest, the preparatory treatment is important. If there is a dry season of several months, the cutting of the forest is usually done then.

COMPLETE FELLING AND BURNING

It was formerly the custom in most countries to cut down the forest and burn the brushwood and trees, after which shade trees were planted.

Some of the immediate advantages of burning are that lining and holing can easily be carried out, thereby saving labour at this stage; certain nutrients are made readily available; the soil is cleaned of certain fungi, weed seeds, and insect pests and their sheltering places. These advantages are, however, more than offset by the deleterious effects. Burning destroys the humus accumulated under the forest, and the stored fertility is thus dissipated in a short period. There is considerable opposition to burning from planters and scientists.

SELECTIVE THINNING

Overhead shade can be provided by leaving a sufficient number of deep-rooted forest trees which can create a canopy for shading the cocoa, and which are not incompatible with its growth. It is better to thin out the forest and leave a sufficient number of the original forest trees as shade, rather than to cut them all out. This method allows all the usual operations of brushing, lining, and holing to be carried out. It has been practised in the Congo with great success. It is also practised in West Africa to a greater or lesser extent, but not with the same degree of skill.

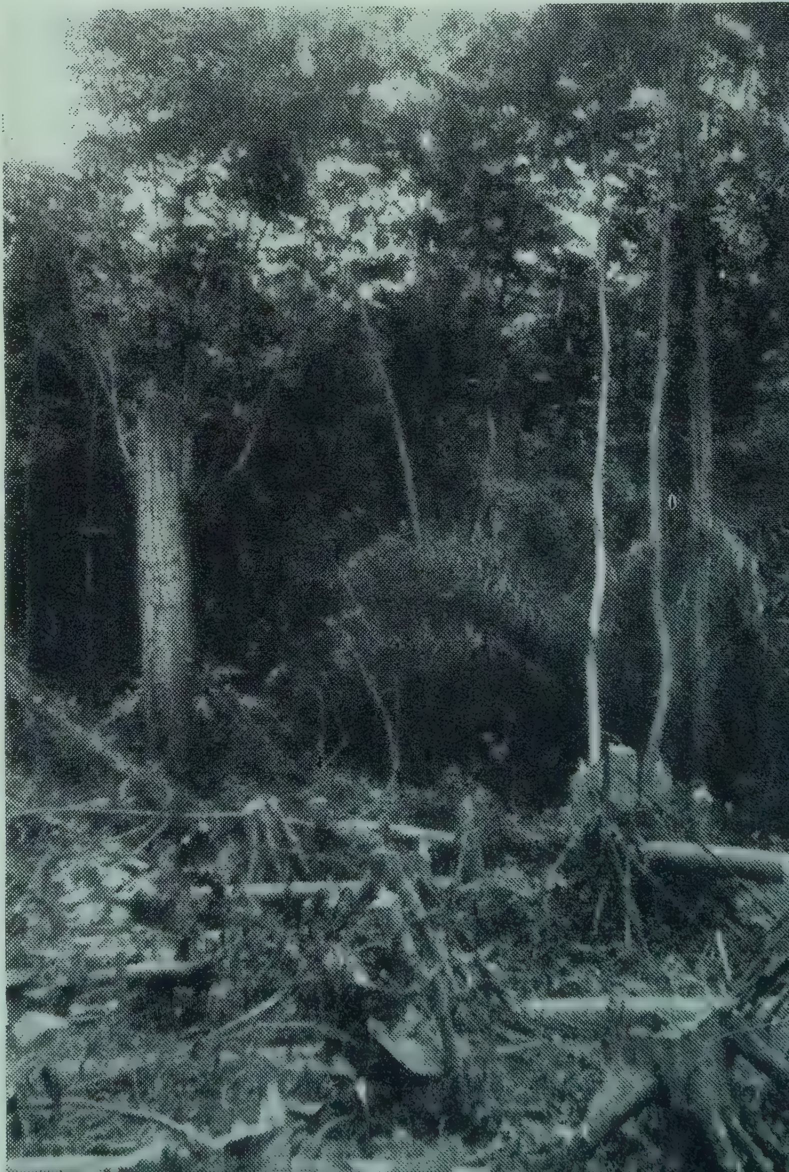
PARTIAL CLEARING

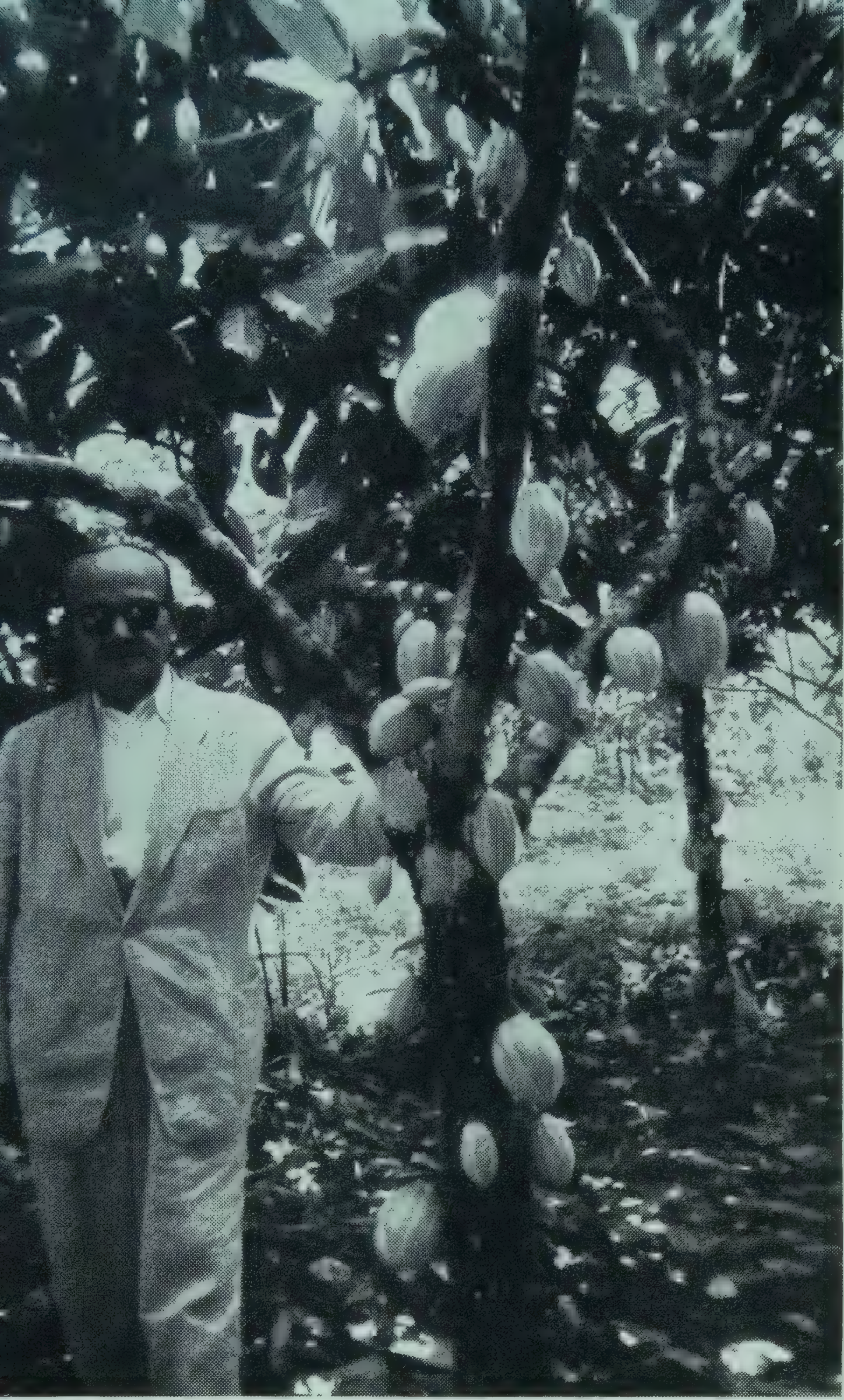
When clearing the lines of trunks and brushwood, some saving in labour can be achieved by merely making a partial clearance in the

9. Clearing jungle in Malaya for cocoa planting. A building for nursery use is in course of erection

10. An old cocoa field cleared and lined for re-planting. This field in Tobago is on a very steep slope

11. Clearing secondary forest in the Gold Coast for cocoa planting
This type of forest is dominated by the Umbrella tree (*Musanga smithii*)





12. A heavy-bearing cocoa tree on a plantation in Brazil

13. Seedlings growing in baskets showing type of basket used and spiral arrangement of leaves on chupon

14. A tree grown from a rooted cutting on an estate in Trinidad. This tree is of the clone I.C.S. 95

15. A seedling nursery at a Department of Agriculture station in the Gold Coas
Shade is provided by tree cassava

first year. If, for instance, the planting distance between rows is to be nine feet, rows can be cleared and planted in the first year at eighteen feet. The tree trunks and brushwood are piled in the intervening space where they will settle down and rot. Incidentally, they provide shelter for the first rows of young cocoa. A year later, the inter-rows are cleared and planted. This method of establishing cocoa is commonly used on the Lukolela cocoa estates in the Congo and is considered to be economical of labour. The result is that the odd-numbered rows are a year younger than the even-numbered rows (or *vice versa*), but this is of no consequence.

It has been a common practice in some South American countries to establish young cocoa in three- to four-foot wide rides or rentices in the forest, the remaining trees being killed off by ring-barking or by the use of arboricides. Under this arrangement, the proper adjustment of shade in the early stages of the plantation's growth is difficult. There may be too much shade at first and too little later.

SALE OF TIMBER

Clearing may be done by the use of daily labour and some or all of the operations may be given out on contract. Where there is timber of commercial value, it may be possible to sell it to offset part of the clearing costs. Where the site is near a settled community, the less valuable timbers may find a sale as firewood or for charcoal-making.

SEQUENCE OF OPERATIONS

In establishing a cocoa plantation it is possible with advantage to vary the sequence of certain operations. In high forest much time is gained by lining, holing, and planting temporary shade before the major felling takes place.

Clearing of the underbrush is usually done early in the dry season. The timing of the operations should be arranged so that conditions are suitable for planting cocoa early in the wet season and for its being well-established before the dry season sets in.

MECHANIZATION IN FELLING

Where the plantation is to be laid out on a large scale, and the forest is to be completely felled as distinct from being selectively thinned, felling by means of drawing through the forest a heavy chain attached to two tractors will speed up the operation. Where reasonably efficient labour is available, however, the cost of this type of

felling would need to be carefully compared with that of felling in the usual way.

For trees up to eighteen inches in diameter, tractor-powered winches are usually better than those which are hand-powered, especially when the ground is soft.

PLANTING IN OLD PLANTATION LAND OR IN LAND WITHOUT FOREST

Where cocoa is to be established on land previously planted with cocoa or another crop, and shade trees are already in existence, most of the operations in establishing the new plantation can be done before replacing the old shade trees. These are carefully felled later and replaced with new trees. The necessity for establishing ground cover and lateral shade at an early stage is as important here as where planting is done in forest country.

If the land to be planted has few trees and little cover, then the first consideration is to plant ground cover, lateral shade, and permanent shade. If time and circumstances permit, the first to be planted should probably be the permanent shade as it usually grows more slowly than the others.

PREVENTION OF EROSION

Unless steps are taken to prevent it, erosion of the soil can take place at all stages in the life of the plantation from the time of first clearing the land. Erosion, in brief, means the removal by water and wind of the humic layer and in due course a part or the whole of the surface soil. The reduced productivity of a plantation can often be traced to the action of erosion in one form or another. Many years may elapse before such a plantation can be restored to a state of fertility.

Prevention of erosion in the opening stages of plantation-making is best secured by leaving a number of forest trees *in situ*, or by planting permanent or temporary shade trees to protect the ground from the effects of wind and rain. Ground cover, in the form of bananas, tannias or other plants commonly used for this purpose, will also prevent erosion if planted in time. The remedy in mature plantations on a slope is contour drainage and the erection of earth or other barriers to check the flow of water.

If the plantation is on a long slope liable to erosion, the cocoa trees should be planted on the contour and tree trunks and brushwood piled along the contour to check the flow of water down the slope. Brushwood and weeds piled in this way will also form an effective barrier against a rush of water.

BENCH-TERRACING

Bench-terracing has long been practised on tea plantations in Ceylon and on rubber plantations in Malaya where these are on slopes or hillsides. Cocoa planting does not lend itself so readily to this practice because it is necessary to preserve the surface layer, and it is usually desirable to leave some forest trees standing, but there are circumstances under which bench-terracing may be practicable. It is one of the most effective measures for preventing erosion, and is therefore worthy of consideration.

DRAINAGE

Where draining is required, the sooner it is done after the land is sufficiently cleared the better. Cocoa may be unaffected by being flooded for several weeks at a time by over-flowing rivers, but is usually adversely affected by stagnant water.

The necessity for draining will be determined by a study of local conditions. When there is a doubt, it is advisable to dig holes six to ten feet deep in order to observe the water-level at different times of the year. The number of drains, and their depth and width, will depend on the lie of the land, the type of soil, and the distribution of rainfall. The drains will naturally be made along the contour, with sufficient fall to ensure that the water drains away gradually. The distance between drains will be adjusted to fit in with the spacing of the rows of cocoa trees.

On all sloping land, drains and roads should as far as possible follow the contour. When making outlets for the drains, erosion can be minimized by widening the outlet into a "fish-tail" shape. If the grass at the outlet is not cutlassed too closely, it will also help to retard erosion.

III. NURSERIES

The Site, Shading and Shelter—Planting Seed—Baskets—Cocoa in Seed Beds—Supply and Treatment of Nursery Plants—Nursery for Shade Trees—Nursery for Rooted Cuttings.

A nursery may be necessary because seed is not available at the time of planting, and because it may be cheaper to grow young plants in a nursery than to supervise them in the field. Where labour is short a large number of plants can be supervised more carefully in the small area of a nursery. During dry spells they are more convenient for watering and they provide a supply of quick-growing plants from which only the better-grown and more vigorous are selected.

THE SITE, SHADING AND SHELTER

The site chosen for the nursery should have a good, deep, free-draining surface soil, within easy reach of an ample supply of water free from objectionable minerals. A gentle slope will make drainage easier. The nursery should be as near the fields as is practicable.

Shading can be arranged by means of bamboo uprights and cross-pieces over which palm fronds are laid, or a more permanent structure can be made with timber scantling and wooden slats. The aim will be eventually to allow about 50 per cent sunlight to penetrate to the young plants for a great part of their time in the nursery. Palm fronds used as overhead covering have the advantage that as they wither with age they become more pervious to light, thus providing automatically the conditions for hardening the young plants in preparation for planting out.

A sheltered site in the forest will not need lateral shade, but where the forest is not available lateral shade can be provided by planting stakes of some quick-growing tree, such as *Gliricidia*, which grows quickly from long cuttings pushed into the ground. The lateral shade will, of course, be planted several months before the cocoa is planted in the nursery, and it will require cutting back, so that maximum shade is provided in the dry season.

Where a more permanent nursery is required, a structure made with timbers which have been treated to resist termite attack may be erected. A series of lean-to roofs made with wooden slats so as to admit the right amount of light will be satisfactory and will prevent most of the rain and dew from falling on the cocoa plants.

There is often a tendency to confine nurseries, especially the larger ones, within too small a space. As most of the transport nowadays is by lorry, sufficient room should be left between different units of the nursery to allow easy passage.

PLANTING SEED

The seed to be planted is usually rubbed with sand or wood-ash to remove the mucilage, but this is not necessary. It is better to plant seeds hilum or scar-end downwards, although they can be planted on their sides. Any other way of planting results in a distorted plant. Good seed should give eighty per cent germination.

BASKETS

Seedlings in baskets have the great advantage that when they are being planted out their roots are not disturbed and they develop in a good soil. The basketed plants are easily handled and transported, and are less liable to damage than where baskets are not used.

The lightest and most durable baskets are made from split cane. Bamboo pots can be used but they may restrict root development and must be removed before planting in the field.

The size of the cane basket is a matter on which opinions vary. Large baskets require more soil or compost to fill them and are heavy to carry. The size will depend to some extent on the size of plant aimed at for planting. Where cocoa is difficult to establish, a larger basket is to be preferred. The Dutch in Java favoured a basket 18 in. to 24 in. deep by about 7 in. wide. The Gold Coast Department of Agriculture recommends baskets which are 8 in. deep, 7 in. wide at the top and 5 in. wide at the bottom. The base of the basket should not be completely woven but should be left as open as possible, with only a few strands across it to retain the soil. This gives the tap-root complete freedom to develop. Cheap baskets can be made by a simple weaving of palm fronds, but will not last long or stand much handling, and are liable to disintegrate before they reach the planting site.

When a great number of baskets is required a contract is usually given to village communities. If baskets have to be made by labour on daily pay they may prove to be an expensive item.

The baskets are filled with good surface soil and some sub-soil, reinforced with compost, leaf mould, or farmyard or artificial manure, unless the original soil is rich. Surface soil alone may be unduly alkaline. They will be renewed from time to time if they have deteriorated, or if the tap-root of the seedling outgrows the original basket. When renewal is necessary, the plant along with its soil is transferred to the new basket and fresh soil packed around it.

COCOA IN SEED BEDS

Where the cocoa seed is to be planted in beds these must be prepared with care. The best available soil should be well worked and mixed with pen manure or decayed vegetable matter and put in a bed slightly raised from the ground. The beds should be divided by paths and made narrow enough to permit of attention to the plants from the paths. When the beds have been slightly consolidated the seeds are pressed into the soil and spaced sufficiently wide apart to allow of being removed by a trowel when ready for transplanting.

SUPPLY AND TREATMENT OF NURSERY PLANTS

Whichever method of raising plants in the nursery is adopted, it is necessary to have a constant supply of healthy, vigorous seedlings to replace casualties in the field during the first 24 to 30 months.

Watering in the dry season can be delayed as long as is consistent with the good growth of the young plants, as once begun it will have to be continued.

Losses will be reduced if the cocoa plants are subjected to a process of *hardening* in the nursery, by gradually reducing the shade to a minimum before they are transferred to the field. Many of the losses in the field are due to damage to the tap-root of the young cocoa plant during transplanting.

NURSERY FOR SHADE TREES

Where shade trees are to be planted as seedlings and not as seed at stake, a nursery for these will be required. The care with which they are raised and planted will vary with the type of trees.

NURSERY FOR ROOTED CUTTINGS

Where the size of the plantation or estate justifies the raising of its own supply of rooted cuttings it is better to do so than to buy them or than to obtain a free supply from a central nursery. A careful selection of material for planting is thus possible. Recent experience in Trinidad shows that where the large central nurseries send supplies to plantations it is impossible to provide clonal plants which are all up to the standard desired by the discerning planter.

IV. PREPARATION FOR PLANTING

Spacing: Close v. *Wide—Optimum Spacing; Close Spacing; Thinning; Practice in Different Countries; Spacing of Shade Trees—Lining: Lining before General Felling; Lining on the Contour—Holing: Treatment of the Soil; Experience in the Gold Coast.*

SPACING

Close *v.* Wide

Spacing, like shading, has given rise to a good deal of controversy. The spacing distances for cocoa vary a good deal from country to country.

Professor Hardy holds the view that the main factor affecting spacing is the root-room in the soil, and that the feeding roots of the cocoa tree will explore the top layer of a soil which has a good crumb structure. As the depth of a good crumb structure varies considerably, so also does the root-room. Where the crumb structure is shallow, planting distances will be greater than where it is deep. In other words, a good soil permits of closer spacing than does a poor soil. This view is shared by Carl de Verteuil of Trinidad.

On the other hand, De Blank, of Huileries du Congo Belge, who has wide experience of tree plantation crops in the tropics, considers that where soils provide less good growing conditions closer spacing is indicated. His theory of productivity is based on the estimated potential production per unit of surface area, which can be determined by multiplying the average individual production by the number of plants on a given area. The optimum density is a function of three factors:

(*a*) The variety to be planted.

(*b*) The potential production of individual trees.

(*c*) The soil and climatic conditions under which the crop is to be grown.

Optimum Spacing

Fashions and practice in spacing have varied from country to country and within countries. Optimum spacing of cocoa is that which gives the greatest yield per unit of land over a given period. Experience so far seems to show that close spacing gives a greater yield in the early years, but where a close and a wider spacing have been compared over a number of years, the yield per acre per annum eventually becomes approximately the same. Close spacing in the early years, with thinning-out as the trees develop, has been

advocated as the best means of getting maximum yields over a long period. Planting by the triangular or quincuncial method at close spacing lends itself more conveniently to thinning at a later stage than where the trees are planted on the square. As long as the trees are in reasonably straight lines which are equidistant from each other, the fact that the trees within the lines may not always be the same distance from each other is of less importance.

Close Spacing

Close spacing has the advantages that the canopy of the cocoa trees soon meets and shades the ground, thereby suppressing weeds, and that if one tree dies the canopy of the adjacent trees soon closes up and covers the intervening space. In West Africa the quick closing of the canopy discourages capsid attack. There is also less tendency for the plant to develop chupons or suckers.

A spacing of 10 ft. by 10 ft. will control weed growth when there is fairly rapid development of the trees. Some consider that there should be a distance of twelve feet between cocoa rows to allow of easy access to the plantation. Whereas in the early years of bearing close spacing makes for higher returns and less expense in weeding, the outlay in plants is greater if selected material is being bought or produced at high cost. This is a point to be borne in mind when close planting is done with the intention of thinning later to provide wider spacing.

Thinning

Where cocoa is planted at close spacing and is to be thinned after seven or eight years, it may be planted 9 ft. by 9 ft. by the triangular or quincuncial method. The first thinning could be done to give a space of just over twelve feet between rows. There is a natural tendency to postpone thinning when a good yield is being obtained from the plantation. If it is unduly delayed, the general shape of the trees is affected and several years may elapse before a desirable form is attained. The time when thinning should take place must be a matter for the good judgment of the planter. When it comes to thinning the plants in the rows, a certain amount of selection may be done. Two good vigorous plants may be left growing close together and weaker plants on either side removed, provided that the gaps left are not too wide.

Practice in Different Countries

In the past Trinidad favoured 12 ft. by 12 ft.; Ceylon, New Guinea and Samoa spaced at 15 ft. by 15 ft. and sometimes 16 feet

I. HEALTHY COCOA TREE IN BEARING : The pods are of Amelonado type.

II. TYPES OF COCOA PODS : (*Left to right*) Two yellow Angoleta, red Amelonado, orange Calabacillo, and two Criollo types.

V. TEMPORARY SHADE FOR YOUNG COCOA : Young clonal trees growing under the temporary shade of bananas.

VI. YOUNG COCOA PLANTATION : Clonal trees growing under Immortelle shade. (River Estate, Trinidad.)

VII. EFFECT OF SHADE : These two-and-a-half-year-old trees form part of an experiment in shading and fertilizing in Trinidad. The small tree has grown without shade. Those in the background were shaded until two years old, when the shade was removed.

VIII. DRYING COCOA : A drying shed with movable roof, typical of plantation equipment in Trinidad. The shed on the right holds the sweat-boxes.

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2

3

4

5

6

7

IX. SECTIONS OF COCOA BEANS AFTER PREPARATION FOR THE MARKET

(1) Unfermented or slaty bean ; compare with (5) a fully-fermented bean of good chocolate-brown colour. (2), (3), (4) Underfermented or purple beans. The bright colour and cheesy cut of these beans indicate that they are little better than unfermented beans. (6) and (7). These purple beans are also insufficiently fermented, although they have been better prepared than those on the left.

A sample of well-fermented cocoa should not contain any beans of the type on the left, and should consist of a high proportion—preferably 100 per cent—of fully-fermented beans like No. 5.

X. COCOA GROWING UNDER FOREST SHADE IN THE GOLD COAST : The cocoa trees are in the centre and background of the photograph.

apart; the Belgian Congo for some years used a spacing of 4 metres by 4 metres, but more recently 3 metres by 3 metres (about 10 ft. by 10 ft.) has been adopted. In experiments in Nigeria where spacings of 8 ft. by 8 ft., 12 ft. by 12 ft., and 15 ft. by 15 ft. were tested on different soils, the best yields were obtained in the early years at close spacing on good soils. The West African peasant farmer, when planting cocoa seed through his food farm, plants closely (3½ ft. to 4 ft. apart), but more recently spacing of 5 ft. by 5 ft. is being adopted. Such cocoa farms are thinned out by the deliberate action of the farmer and some trees are killed off by pests and diseases, but the final stand is usually very close-spaced when compared with the standards in other countries.

Attention must be given to the matter of filling the land to capacity, while making provision for the labourers to walk between the lines with dusting and spraying equipment.

Spacing of Shade Trees

The shade trees will normally be planted in line with the cocoa trees, and the spacing will depend on the size which it is expected they will eventually attain and on the nature of their canopy. *Erythrinas* in Trinidad were sometimes planted at 24 ft. by 24 ft. and later thinned out to 48 ft. by 48 ft., or at 15 ft. by 15 ft. and thinned to 30 ft. by 30 ft. The latter spacings were intended to allow the trees to grow to full stature. Where control of the growth of the shade tree by topping and cutting back the branches is envisaged a closer final spacing would be adopted. Bananas and plantains are usually planted at 12 ft. by 12 ft. in the rows of cocoa.

LINING

Lining is necessary in order to place the trees in such a way that the maximum use is made of the available space, and so that the lines of trees are eventually placed as nearly equidistant as is practicable. It is usual to work from a base line which may be across the field or along one side and the lines will generally be orientated in a north and south direction.

Lining before General Felling

If before general felling in forest country it is desired to plant lateral shade and/or permanent shade, or even cocoa itself, lining can be done immediately the underbrush has been cleared.

Lining Methods

The siting of the trees may be such that every four form a square or every three form an equilateral triangle. The latter method is

more economical of space and allows of more trees being planted per acre. When stakes are placed to mark the sites for cocoa trees, other stakes will be inserted to mark the position of permanent shade trees.

Lining on the Contour

On hilly land it is most desirable to line on the contour. This will enable soil conservation measures to be applied more easily, and if the distance between the contour rows is twelve feet or more other operations will be made easier. This distance will permit of the mechanization of certain operations.

HOLING

Holing is designed to provide suitable conditions in which the plant may develop a root-system and establish itself.

In an easily worked fertile soil there is less need for a large hole than in a stiffer soil. Where the soil is heavy the fork is better for digging than the spade, as the latter tends to make the sides of the hole impervious to water. It is more important that the hole should be wide than that it should be deep, because the feeding roots spread outwards, and the tap-root will in any case penetrate a long way below the bottom of the hole. A diameter of two feet or more with a depth of twelve to eighteen inches is a convenient size. Where rocks or large boulders are present, it is well to probe the bottom of the hole for a foot or more with a sharpened iron to ensure that there is none underneath. A similar precaution should be taken where there is the possibility of hardpan or an impervious clay layer.

Where the plants are grown in baskets, the necessity for a large hole is not so great as when they are being transferred from nursery beds. If the seed is to be planted in the field, a good-sized hole should be made and great care taken to fill it with a soil mixture in which the plant can grow.

Treatment of the Soil

It is convenient when holing to keep the surface- and sub-soils separate. The holes should be filled with a friable mixture of a good deal of surface soil and some sub-soil. Surface soil alone may be too alkaline. For the same reason a concentration of wood ash is to be avoided. When it is desired to reinforce the mixture well-rotted compost or manure is added. If the soil is piled up in a mound over the hole it settles down to ground level. On the other hand, a

saucer effect around the plant, due to insufficient soil in the hole to begin with or to the soil having been scraped away in the course of weeding, may give rise to waterlogging.

The soil around the hole should be well hoed before the plants are inserted as the feeding roots develop most quickly when the soil has been opened up by cultivation.

Experience in the Gold Coast

Although much of what has been described here may be considered as orthodox practice and represents that adopted by successful planters in the West Indies and the Americas, experience in the Gold Coast does not completely support this. Here it has been found that, when seed is planted "at stake," i.e. directly in the plantation, the less the soil is disturbed after cleaning and brushing the better. Deep cultivation tends to retard rather than accelerate the progress of the plant.

There is some doubt here whether there is any advantage in making holes before planting seed at stake, and good results have been obtained without holing. The best results follow the opening of holes immediately before planting, and not when they have been made some time in advance and left to "weather," which is recommended as good practice in other countries. When cocoa seedlings have been planted out in baskets they have grown better when a hole is made of just sufficient size to receive the basket and the soil surface is not otherwise disturbed.

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Chapter VI

THE COCOA PLANTATION (2)

VEGETATIVE PROPAGATION OF COCOA BY ROOTED CUTTINGS, WITH NOTES ON SOME OTHER METHODS

History of the Development of Rooted Cocoa Cuttings—The Nursery—Collecting Cuttings—Preparing the Cuttings—Propagators—Preparation of Rooting-bin—Striking, or First Stage in producing Roots on the Cuttings—Conditions inside the Propagator—Hardening—Rooting in Open Beds under Mist Spray—Use of Greenhouses and Humidifiers—Storage of Potted Plants—Review of Propagation Methods—Labour Requirements—Other Methods of Propagation.

It is well known that cocoa seedlings do not usually reproduce the characteristics of the parent trees, whereas plants derived from vegetatively propagated material consistently do so.

The method of vegetative propagation of cocoa most widely adopted in recent years for large-scale multiplication (both for experimental work and for planting on estates) is that of rooted cuttings.

HISTORY OF THE DEVELOPMENT OF ROOTED COCOA CUTTINGS

The results of the selection of material from high-yielding trees on estates in Trinidad indicated the need for a rapid means of multiplying the selected trees in order to provide the necessary plants for experimental work.

Pyke evolved a method for the propagation of cocoa from semi-hardwood cuttings, and this initial work was carried further by Cheesman and Spencer, aided by the use of root-inducing hormones.

Posnette used this system for cocoa propagation at Tafo in the Gold Coast.

The Trinidad Cocoa Board installed a propagating centre at La Pastora during the last war for the purpose of putting superior cocoa material at the disposal of planters. At that stage large-scale production of rooted cuttings demonstrated that heavy losses were incurred

by the methods employed, and it was obvious that further research work must be done if satisfactory multiplication on a commercial scale was to be achieved.

In 1949, Dr. Harry Evans joined the Botanical Section of the Cocoa Research Scheme as Senior Plant Pathologist. His research work resulted in spectacular improvements in the methods of rooted-cutting production. Most of this chapter is based on his published and unpublished work.

The process of producing rooted cuttings entails the use of a nursery of selected plants from which the supply of cuttings or plant material is to be derived. The cuttings, after being treated with a root-inducing hormone, are placed in propagating-bins or beds which have been filled with suitable material, such as sawdust, coconut fibre dust, or other rooting medium. While they are in the bins or beds, they are kept in favourable conditions of temperature and humidity and given the desired degree of light, and, when in due course they develop roots, they are usually transferred to baskets for the first stage of hardening. At this stage they have still to receive a considerable amount of careful attention as regards watering and regulation of light and temperature. On passing through this stage, they are set out for the final stage of hardening and development before planting in the field.

While the above is an outline of the procedure generally followed at the present time, there are many variations.

It may be said that in most countries the production of rooted cuttings calls for a considerable degree of skill and attention to detail. Nevertheless, it is no longer regarded as something that can only be done by the scientist. Many planters and plantation companies are producing rooted cuttings for their own use after a study of the literature on the subject.

NURSERY

It is desirable to have the nursery of trees which supply the cuttings conveniently near the propagators. Vigorous, healthy trees, free from mineral deficiencies, provide the best cuttings, and so a well-drained loamy soil, rich in organic matter, is indicated. Where the soil is below the quality required, it has to be enriched by the supply of compost and pen or mineral manures. A soil tending towards acidity (pH value 5·0 to 6·0) is recommended.

Good shading arrangements are necessary to enable the nursery plants to produce a supply of soft branches in a suitable condition for rooting; over-exposure to sunlight may cause poor rooting results.

As a general guide, 25 per cent to 50 per cent full sunlight falling on the nursery trees will be satisfactory.

The trees used for shading the nursery plants are usually those which grow quickly from cuttings, such as *Gliricidia maculata, Erythrina poeppigiana*, and certain species of *Inga*, but this by no means exhausts the list of trees which may be used. Apart from quick growth, the main essential in a shade tree is foliage which allows of filtered light reaching the nursery plants. Plantains and bananas have also been used to provide shade, but are liable to be blown down and cause damage.

Emphasis has sometimes been laid on the advantage of using leguminous shade trees, but non-leguminous trees can be used equally well.

Shade trees have to be cut back from time to time and controlled to give a suitable degree of shade and light. Where there is a marked dry season, they have to be cut well back before the end of the wet season, so that they may develop thick foliage and provide a greater amount of shade during the dry season.

The spacing at which the shade trees will be planted will depend on their habit of growth. *Gliricidia*, which is employed as nursery shade in Trinidad, is usually planted at 10 ft. by 6 ft.

A common spacing adopted for the cocoa trees is 6 ft. by 4 ft. The planting-holes are usually filled with surface soil, reinforced with pen manure or compost.

The age at which the young tree will yield cuttings will depend on its vigour and speed of growth. As it is necessary to allow the plant to develop, not more than three cuttings may be expected in the first year. The number of cuttings that may be expected from nursery trees up to five years old may be of the following order: up to one year, three cuttings; next two years, twenty to thirty cuttings, but in the following two years a much smaller number are cut. It is usual to replace the tree at five years old, or earlier, depending on its performance.

Although the removal of cuttings automatically prunes the tree, it is necessary from time to time to prune the tree back severely in order to induce a flush of new growth. This is done at the end of the dry season, the trees having been manured beforehand.

When the trees are subjected to repeated removal of cuttings over a period they will require frequent applications of N.P.K. fertilizers. An application of 1–1½ lb. of fertilizer per tree per annum, supplemented with some pen manure, should meet requirements.

The area of the nursery will, of course, be related to the area of plantation to be established each year. One acre of nursery planted

at 6 ft. by 4 ft. will contain about 1,800 plants. Assuming twenty cuttings per tree per annum, and allowing for casualties at all stages, one acre of nursery should produce enough plants to establish thirty-six acres of cocoa which, planted 9 ft. by 9 ft. in the field, gives 540 trees per acre.

COLLECTING CUTTINGS

Cuttings are taken from recently matured flushes when the leaves are fully green. They should have at least three leaves, and the stems should be green but hard, or semi-hard. They are often referred to as "semi-hardwood cuttings." The upper surface of the stem will usually have turned a shade of brown at this stage but the under surface will still be green (see colour plates III and IV). Greening of the leaves may be delayed when the soil is deficient in certain nutrients, and it is then better to wait until the leaves are green, even if the other conditions of the cutting indicate that it is ready for removal from the parent tree.

If it is desired, for the sake of economy in material, to use single-leaf cuttings, these should be cut at an earlier stage of development when the stem is still green on the upper surface. If two buds are left on the semi-hard stem from which the single-leaf cutting has been removed they will sprout quickly and give further cuttings. This point is mentioned because buds farther down on the hard stem are dormant and will not develop so quickly.

In general, stem-cuttings should be used as they develop more quickly than single-leaf cuttings, being ready for planting in five to six months. The single-leaf method is used when cuttings are in short supply and the demand for plants is high. Single-leaf cuttings take an extra two to three months before they are ready for planting.

Those parts of the nursery tree which have been attacked by insect pests or fungi, or trees which show signs of serious mineral deficiency, are to be avoided, as such material may give trouble in the propagator.

Cuttings are removed from the tree by a cut just above a node, and may vary in length from five to twelve inches and bear three to seven leaves. Where there are well-defined wet and dry seasons, flushes will grow longer in the wet season, particularly at the beginning, and not so long in the dry season. Where it is desired to get the maximum number of cuttings from the nursery, it may be advisable to use the longer flushes for single-leaf cuttings during the wet season and the shorter flushes of the dry season for stem-cuttings. As the former take longer to develop than the latter, plants of similar size will be available for planting in the following wet season.

Normal practice in Trinidad is to take the cuttings by 8.30 to 9.30 a.m., and only on wet and humid days can they be taken throughout the day. They are placed immediately in a bucket of water to keep them in a moist condition and in due course they are placed in the propagating-bins.

PREPARING THE CUTTINGS

(*a*) *Stem-cuttings.* The lower leaves are removed by a clean cut close to the stem, leaving three to six leaves, according to the length of the cutting. The longer leaves are cut with scissors to half or a third, depending on the original size. Leaves up to six inches long are left untouched. The purpose of trimming is to prevent mutual shading, and to accommodate a greater number of cuttings in a given space.

After the leaves have been trimmed, a small piece of the base of the stem is cut off to provide a fresh surface, and the base of the stem is immediately dipped in a root-inducing hormone. The hormone mixture which has had greatest success was α naphthalene-acetic acid and β indole-butyric acid, used as a concentrated dip. This mixture is made up by dissolving 0·4 grams of each acid in 60 ccs. of 95 per cent alcohol and adding 40 ccs. of water.

(*b*) *Single-leaf cuttings.* Single-leaf cuttings are not taken, as such, from the tree, but cuttings of a similar size to stem-cuttings are taken and later divided into single-leaf cuttings.

In preparing the single-leaf cutting for the propagator, the terminal bud is removed and the shoot is divided by cutting the stem about ¼-inch above each node. The leaves are cut back as for stem-cuttings.

The hormone described above for stem-cuttings is diluted with 50 per cent alcohol to reduce it to half-strength for single-leaf cuttings.

In the case of both types of cuttings, where infection with fungi is suspected, subsequent trouble in the propagator may be avoided by dipping only the leaves in Bordeaux mixture before dipping the base of the stem in the hormone mixture.

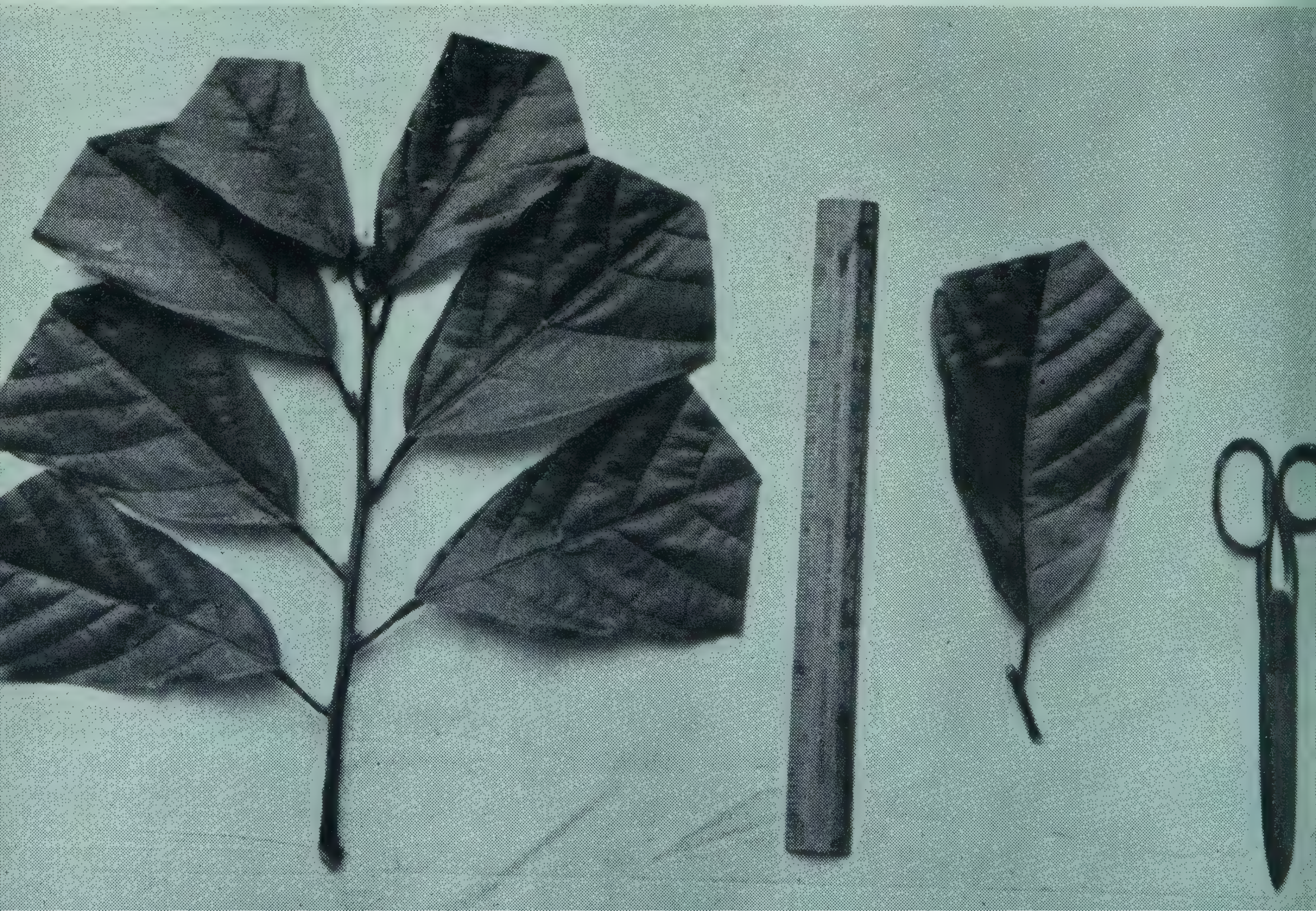
PROPAGATORS

Propagating-bins may vary in size from a small single compartment unit to a battery of several bins. A convenient size for a single compartment is 4 ft. to 5 ft. long by 3 ft. wide by 2 ft. 8 in. deep. Surface dimensions may be varied from 3 ft. by 3 ft. to 9 or 10 ft. by 3 ft.

16. Nursery trees under *Gliricidia* shade, Trinidad

17. The equipment used in preparing stem-cuttings: A bucket for collecting cuttings, a bottle of hormone solution, and a dish to hold the cuttings after preparation

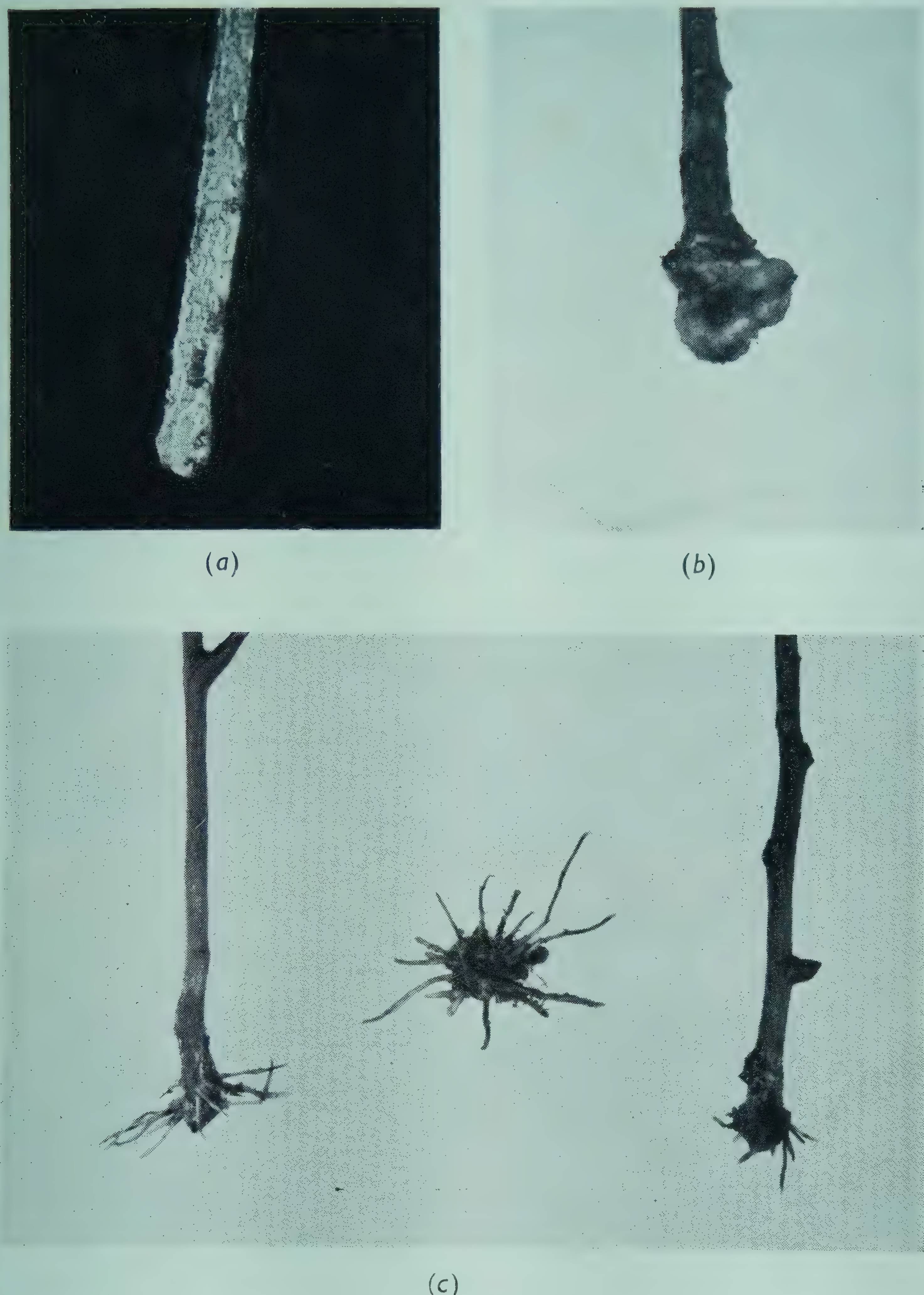
18. Stem- and single-leaf cuttings trimmed and prepared for the rooting-bin



19. Propagating-bins under construction. Stones and gravel for drainage have been placed in the bins; those in the background have also been filled with a rooting-medium. The two types of roof over storage space can also be seen

20. A battery of rooting-bins; the glass frames are covered with a layer of cloth t
reduce light intensity; the light spray of water keeps the bins cool

21. Watering the cuttings by means of a perforated pipe installed inside the bin; he
the bins are covered with a layer of cloth



22. Effect of moisture conditions on rooting

(*a*) Over-watering and inadequate aeration: callus rods developing

(*b*) Under-watering and excessive aeration: a basal callus pad has developed

(*c*) Optimum conditions: these cuttings have started to root well; the middle photograph is an end-on view of the base of a cutting

(a)

(b)

23. Effect on leaves of abnormal conditions in rooting-bin

(a) Excessive loss of moisture due to failure to maintain a high humidity causes patchiness which can be seen above; these patches are yellow

(b) Inadequate light intensity leads to carbo-hydrate starvation which is shown by yellowing areas

Potting rooted cuttings.
baskets are nearly filled
potting mixture before
cuttings are put in

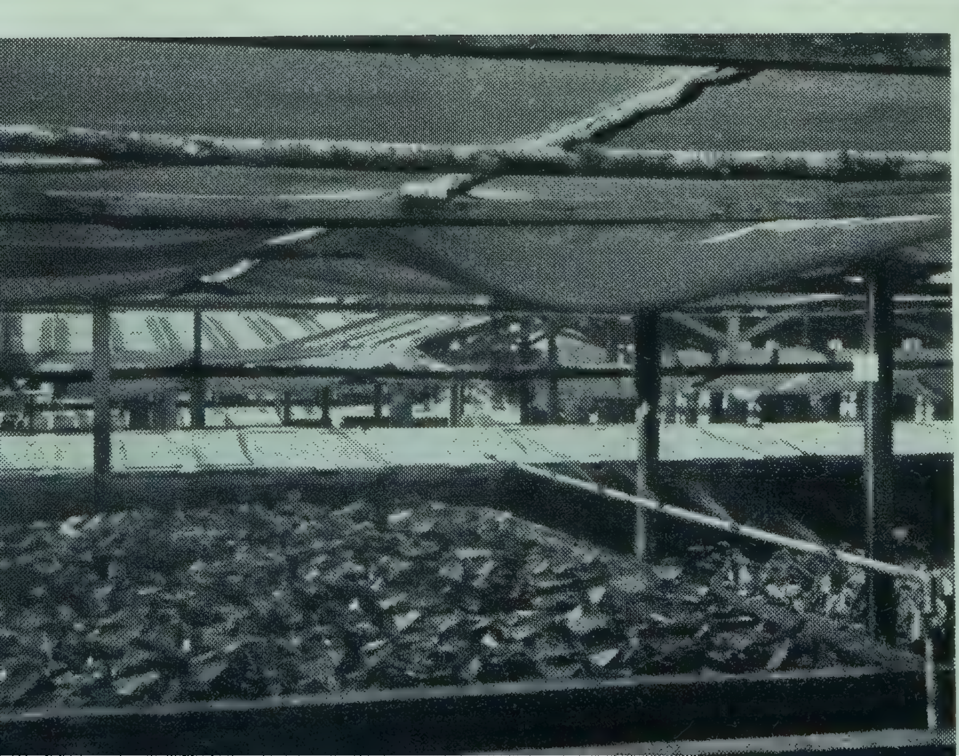
25. Rooted cuttings with their first flush

(*a*) Stem-cutting

(*b*) Single-leaf cutting

26. Storage space for rooted cuttings. The floor is concreted and the roof consists of alternate panels of glass and corrugated sheets

27. Storage space; the cuttings are shaded with camouflage netting



28. Open spray bed with lines of T-jets on both sides

Unless fixtures for automatic spraying are provided inside the bin, there is a tendency for the relative humidity to drop in the larger chambers.

A convenient lay-out is a battery of bins built in two rows of six compartments each.

The walls of the bins may consist of brick, stone, or reinforced concrete; temporary bins can be constructed of wood. The floor is usually of concrete, and drainage holes are provided at the base of the walls.

The bins are covered with close-fitting frames made of wood or metal, fitted with glass or other transparent material, such as plastic. Metal frames, although usually costly, are more durable. The frames are covered with cheap calico or old newspaper, which is kept damp by watering from perforated pipes or with a watering-can. The evaporation from the covers helps to keep the temperature within the bins from rising unduly.

Overhead Shading of Propagators

This may conveniently be provided by a framework erected eight feet or so above the propagators; camouflage-netting, wood-slats, or split bamboo will serve the purpose. The aim is to admit 25 per cent to 30 per cent incident light. The lower limit is required in periods of prolonged sunlight, and the upper limit in times of cloudy weather or overcast skies.

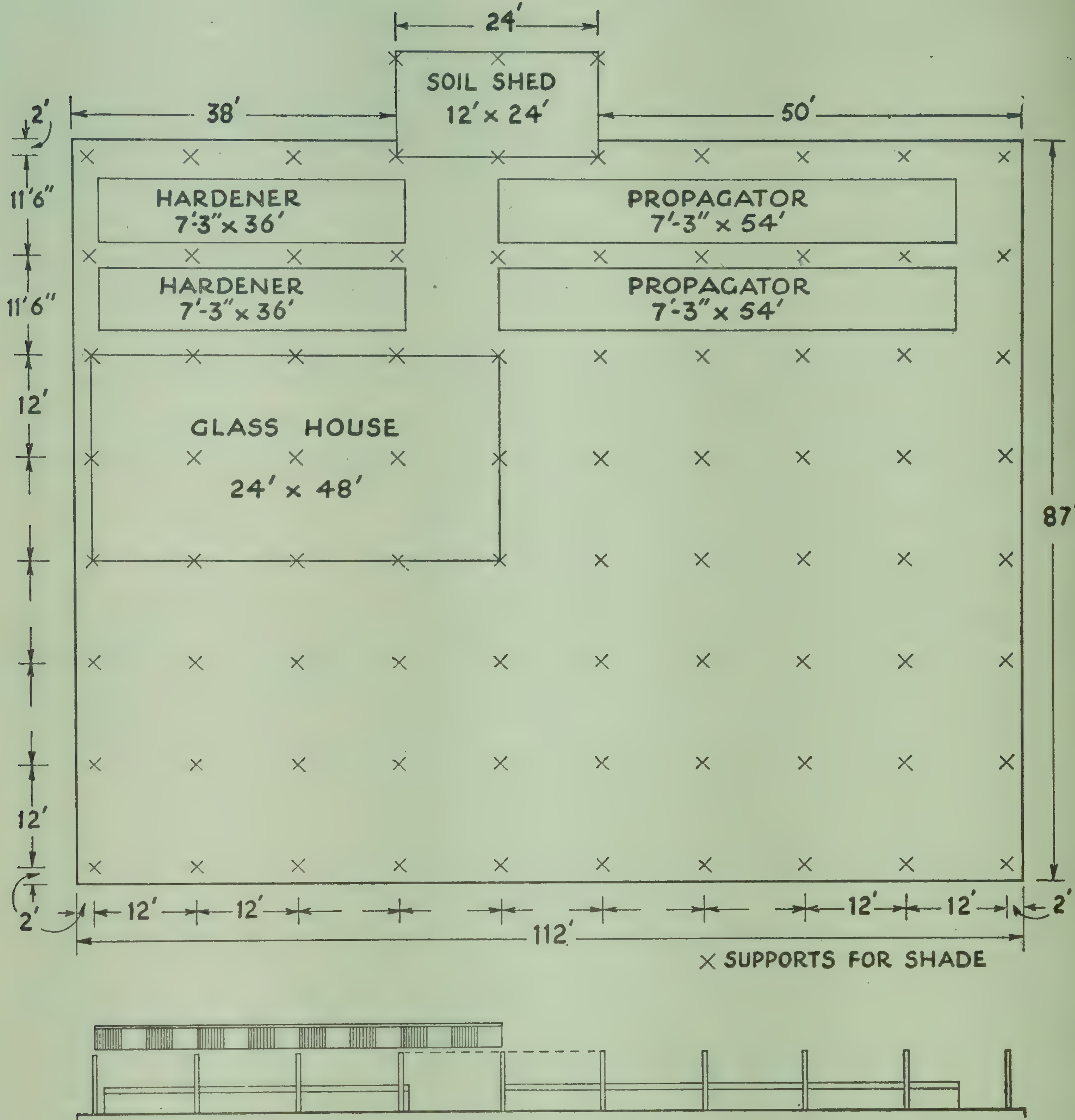
With lath or bamboo shade, the space between the laths can be adjusted to give the desired degree of sunlight.

The bin covers transmit about half of the incident light so that, where the overhead shade transmits 20 per cent, the light penetrating the bin is about 10 per cent. This light intensity will be found suitable for most of the year, but on very bright days in the dry season it may be necessary to place an extra layer of cloth or newspaper on the bin covers.

PREPARATION OF THE ROOTING-BIN

The bottom of the bin is covered with a layer of stones, followed by a half-inch to one-inch layer of pebbles. Over this lies a nine-inch layer of rooting-medium or other material in which the cuttings are to be placed. The layer of stones will facilitate drainage and the layer of pebbles will prevent the rooting-medium from being washed away.

For many years various grades of sand were used as the rooting-medium, and good results were obtained where it was of uniform

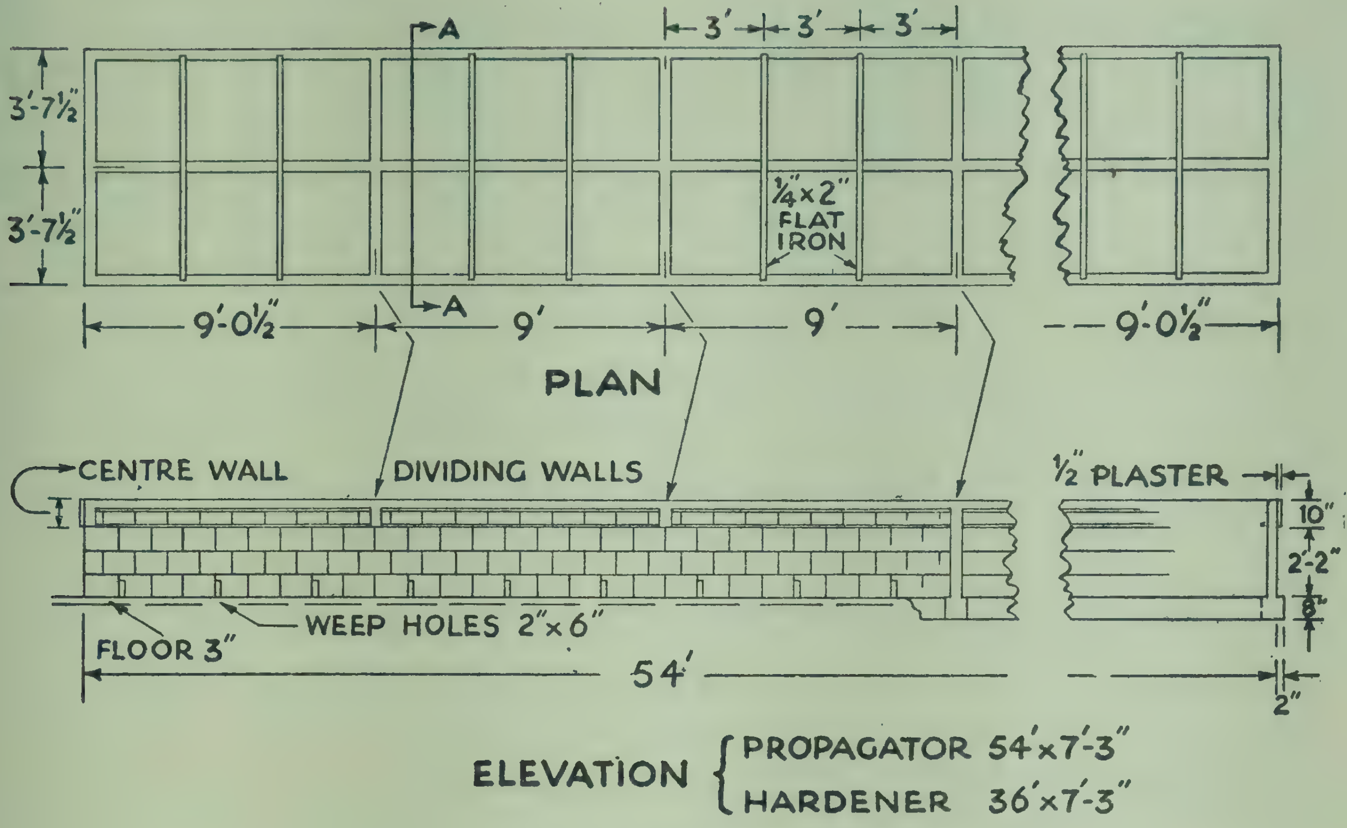


(*a*)

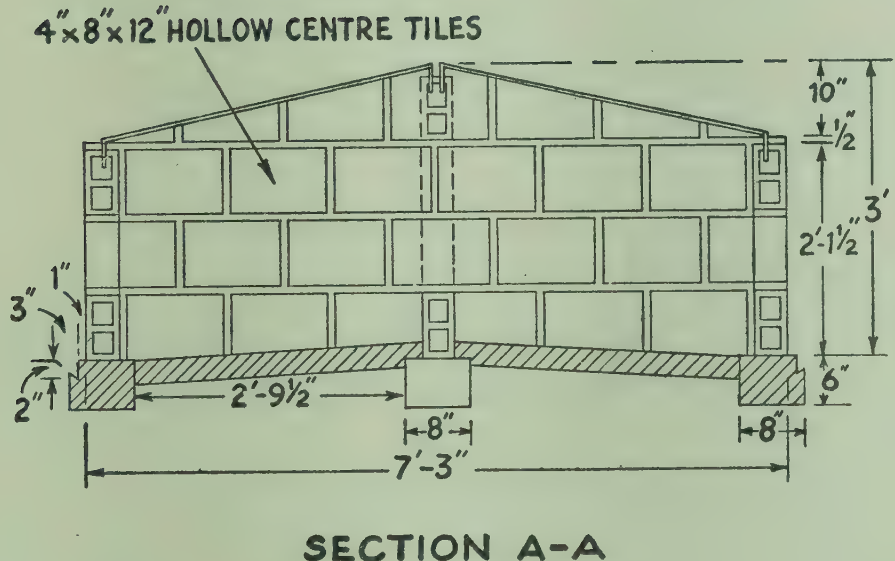
FIG. 3

ESTATE PROPAGATING STATION WITH A CAPACITY OF 10,000 PLANTS PER ANNUM

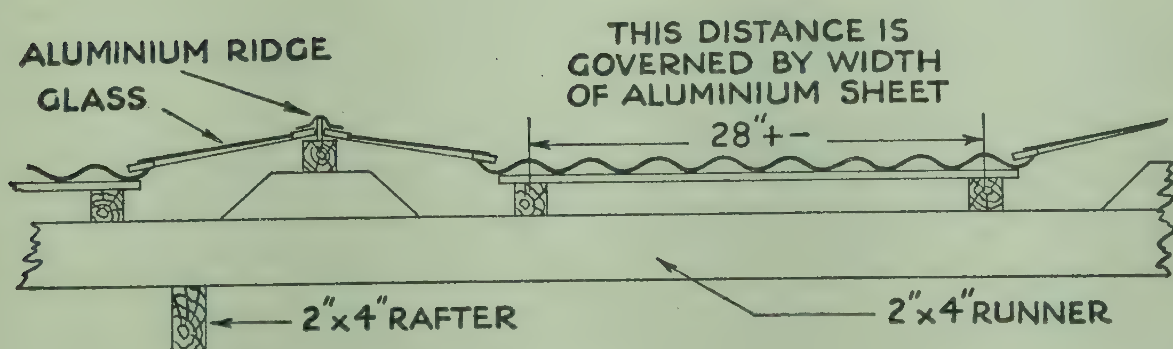
(*Above*) (*a*) Plan and elevation of complete unit.
(*Opposite*) (*b*) Plan and elevation of propagating-bins;
(*c*) Section of above;
(*d*) Detail of construction of glasshouse roof.


A
3'
3'
3'
3'-7½"
3'-7½"
¼"×2" FLAT IRON
9'-0½"
A
9'
9'
9'-0½"
PLAN
CENTRE WALL
DIVIDING WALLS
½" PLASTER
10"
2'-2"
8"
WEEP HOLES 2"×6"
FLOOR 3"
54'
2"
ELEVATION
PROPAGATOR 54'×7'-3"
HARDENER 36'×7'-3"

(b)


4"×8"×12" HOLLOW CENTRE TILES
10"
½"
3'
2'-1½"
1"
3"
6"
2"
2'-9½"
8"
8"
7'-3"
SECTION A-A

(c)


ALUMINIUM RIDGE
GLASS
THIS DISTANCE IS GOVERNED BY WIDTH OF ALUMINIUM SHEET
28"+-
2"×4" RAFTER
2"×4" RUNNER

(d)

grain size (1 to 2 mm.), if the watering schedule was adequate. Of recent years organic rooting-media have been demonstrated to be better than sand. The Imperial College of Tropical Agriculture uses composted sawdust exclusively. The residual dust obtained from the preparation of coconut fibre is a good rooting-medium and can be used without composting or other preparation. The heat-expanded micaceous mineral known as Vermiculite makes an excellent medium. It is used in horticulture and in the building trade in temperate climates, but it is expensive and is not always easily obtainable in the tropics.

Organic rooting-media last for six to eight months, after which time they will decompose and lose their texture. Decomposition is accelerated by heavy watering. A simple test to decide when it is time to renew the composted sawdust is to squeeze it in the hand; if it hangs together on being released, it is due for renewal. Vermiculite will also tend to pack and lose its texture after a time.

Where sand is used, it is important that it should be of uniform grain size. Although coarse sand needs more watering, it is preferable to fine sand, because the amount of water applied admits of greater variation. In order to maintain a high humidity in the bin, coarse sand should be watered more heavily but at less frequent intervals than fine sand. Fine sand requires watering little and often.

This does not exhaust the list of rooting-media, and no doubt other suitable materials will be discovered.

STRIKING, OR FIRST STAGE IN PRODUCING ROOTS ON THE CUTTINGS

(*a*) *Stem-cuttings.* The cuttings are pushed into the rooting-medium to a depth of three to five inches, being planted at the greater depth when the medium is new and at shallower depths after the medium has been in use for some time.

They are inserted with a backward slant in staggered rows so as to avoid mutual shading. The density of the cuttings in the bin will, within limits, depend on their size and the amount of bin space. Normally, thirty cuttings per square yard are set but, if bin accommodation is restricted, up to twice as many may be set, though in this case rooting percentage will be lower.

(*b*) *Single-leaf cuttings.* These are placed in rows four to five inches apart, with the leaf held between a pair of stout wire rods for support. (The rods are usually painted with black asphaltum paint to prevent symptoms of metal toxicity developing on the leaves.) The stem is planted 1 inch to $1\frac{1}{2}$ inches in front of the rods so that

the leaf blade will slant backwards. The stem cannot, of course, be planted deeply as the bud must not be covered. Some eighty to ninety of these cuttings can be accommodated in a square yard.

CONDITIONS INSIDE THE PROPAGATOR

It is very important that the conditions of light, temperature, and humidity in the propagator should be correct.

A cocoa-cutting will transpire rapidly and, as it has very little absorptive capacity until a good root system has been developed, transpiration must be reduced to a low level by keeping the humidity within the bin as near 100 per cent as possible. This is achieved by frequent watering, thus preventing a rise in temperature, as it is more difficult to maintain 100 per cent humidity with a rising temperature.

Light and temperature interact, and as more light strikes the bin cover, the temperature will rise; the temperature must be kept below 30° C. (86° F.) to obtain good results.

In Trinidad, where the light is very bright for most of the daylight hours, a temperature of 28°–30° C. and a light intensity of 10 per cent of full sunlight give good results.

The light intensity is controlled by the overhead shade and cloth on the bin covers, and the temperature is controlled by watering.

Two main objects in watering the cuttings are (*a*) to maintain almost 100 per cent humidity in the bin, and (*b*) to maintain an optimum air-moisture relationship in the rooting-medium. Where the organic rooting-medium has been well watered before setting the cuttings, it should only be necessary to spray the cuttings lightly every two hours in order to maintain humidity. It is most important that the amount and frequency of watering should be correct. The correct watering schedule can generally be arrived at by a few comparative experiments. On bright days in Trinidad, for example, when sand is used as the rooting-medium, the cuttings are watered five times a day from 7 a.m. to 3 p.m., the water being spread evenly in the bin.

In large-scale propagators it is usual to install spray nozzles inside the bins so that a whole battery of propagators can be watered by opening a tap.

The correct watering schedule can be judged from the behaviour of the base of the cutting. When the rooting-medium is badly aerated and over-watered the base of the cutting may rot. In a less severe condition of over-watering and under-aeration, white callus rods protrude through the small lenticels or pores in the bark. This effect

may also be brought about by using too strong a solution of root-inducing hormones or by leaving the cuttings too long in the hormone. If, on the contrary, the rooting-bed is over-aerated and insufficiently watered, a thick pad of callus is formed at the end of the cutting and rooting is greatly delayed.

Some clones root much more readily than others, and certain clones are very difficult to root, so that the proportion of cuttings rooted will depend on the clone used. Cuttings from healthy trees may be expected to root in fourteen to twenty days.

HARDENING

When the cuttings have rooted satisfactorily, they are potted out and placed in hardeners. The term "hardening" is here used in the sense of acclimatizing a plant not to a lower temperature but to a lower humidity. The root system of the cocoa-cutting must develop considerably during hardening so that it can supply the plant's need for water.

The cuttings are removed from the rooting-bin and potted in baskets. The potting-mixture consists of 2 parts of soil to 1 part of sawdust compost. Fertilizers should be mixed in with the potting-mixture at the rate of 1 oz. of superphosphate, 2 ozs. muriate of potash, and 4 ozs. sulphate of ammonia per bushel. These should be mixed at least ten days before the potting-mixture is to be used.

The rooted cuttings are planted firmly in the baskets, watered well, and placed immediately in the hardening-bins. These are built on the same lines as the rooting-bins but are not so deep. The plants can receive more light, so the lids are not covered with cloth but overhead shade remains the same. While the plants are in the hardening-bin, they are lightly watered three or four times a day in order to maintain the humidity. When roots can be seen emerging from the baskets, usually after six to ten days, the covers can be lifted six inches. Two or three days later the plants can be transferred to a shaded greenhouse. Thus the whole hardening process lasts ten to fourteen days.

Hardening in the Bin

By the use of an organic rooting-medium, cuttings can be hardened in the rooting-bin. This may save time and will certainly save space, particularly with single-leaf cuttings. The procedure is simply to leave the cuttings in the bins for eight to ten days longer than normal; at the end of that time the covers can be raised for two to three days before potting. In this case, greater care will have

to be taken in potting, as the roots are much longer. After potting, the plants are placed in the greenhouse and frequently sprayed with water for a few days, particularly if the humidity is below normal.

ROOTING IN OPEN BEDS UNDER MIST SPRAY

The conditions required inside a closed bin have been described. Similar conditions can be achieved in an open bin under a mist spray, but here light and temperature do not interact in the same way because the temperature is always kept down by the falling spray. More light may, therefore, be allowed to fall on the cuttings. Overhead shade normally admits 20 per cent to 25 per cent full sunlight, as mentioned earlier.

The open bed has a surrounding wall, twelve to eighteen inches high, enclosing layers of rock and pebbles which are covered with a rooting-medium, as already described for the rooting-bin. These beds are usually rectangular in shape and are watered from a central or peripheral pipeline.

In Jamaica circular open beds are used, each surrounded by a wall of aluminium sheets. The bins are watered by tee-jets mounted on a pipeline installed round the propagating bed.

The air-moisture relationship in the rooting-medium will be determined by the water pressure, the type of nozzle used, and the medium itself. The open-bed system uses more water than closed bins and it is usually the nature and adequacy of the water supply, together with the water pressure, which determines whether this method should be used. Normally, a pressure of at least 50 lb. per square inch is needed for proper functioning of the jets and this must be constant during daylight. A water supply containing any toxic salts like sodium chloride, or with a high lime content, is to be avoided.

Tee-jet nozzles have been successfully used; they consume six to eight gallons per hour and with this quantity falling on about twelve square feet of the open bed, an organic rooting-medium can be used. Skinner nozzles, which consume much more water, can be employed when coarse sand is used.

The cuttings are planted in the medium and the spray is turned on from soon after sunrise until sunset. With this heavy fall of water on the leaves, there will be some leaching of nutrients out of the leaves and, where cuttings are suffering from mineral deficiency, losses may occur through leaf breakdown. It is important to have good healthy cuttings when using this system.

When rooting single-leaf cuttings in open beds, it is usually preferable to use a free-draining rooting-medium, such as coarse sand, and

employ a fine spray, as the water falling on the leaf runs down the stalk and is liable to cause waterlogging at the base with any but free-draining rooting-media.

It takes some time for single-leaf cuttings to set roots in an open bed, and this seems to be so particularly in large-scale production. Under these conditions there may be losses due to wilting.

USE OF GREENHOUSES AND HUMIDIFIERS

A large-scale method of hardening has been developed by means of a greenhouse in which a humidifier is installed.

The greenhouse consists of a framework fitted with glass panes or transparent plastic material. The dimensions of the house may be 18 ft. by 10 ft. by 8½ ft. Inside the house are four tiers of movable shelves at intervals of two feet, supported by light girders made of aluminium alloy, "Dexion" being commonly used. The roof of the house requires to be shaded; camouflage netting is suitable for the purpose. A house of the dimensions mentioned above will accommodate about 3,000 plants where the floor is used as an extra tier.

The humidifier provides a fine spray which keeps the atmosphere at 100 per cent humidity throughout the day. A Bahnson centrifugal humidifier, operated by a ¼-h.p. electric motor, has been used successfully for this purpose, the water consumption being only about eight gallons per hour. This humidifier is capable of meeting the needs of a greenhouse holding 5,000 plants. Other fittings, such as overhead pipes and tee-jets, can, as an alternative, be installed in the greenhouse to provide humidity.

With the humidifier continuously in operation during the day there are present all the necessary factors for rapid development of the root system and rapid hardening of the cuttings. Light intensity is adequate, the water supply to the plants is optimum, and the potting-mixture is never over-watered. Roots are seen emerging out of the baskets in four to five days and even inadequately rooted cuttings are generally hardened within ten days. The plants are then taken straight out into a cool, shaded greenhouse.

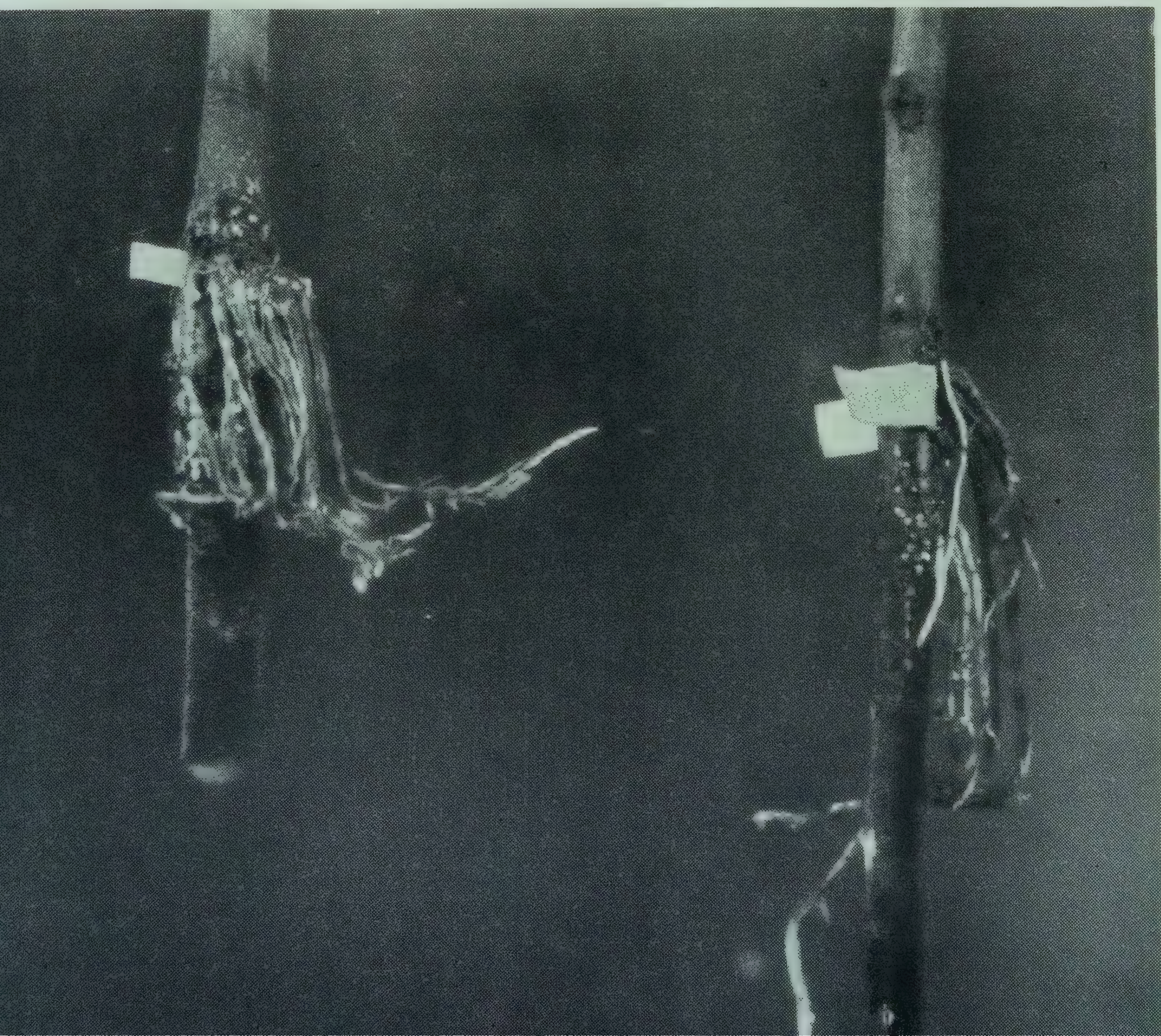
STORAGE OF POTTED PLANTS

The potted plants will have to grow for several months (five months in the case of stem-cuttings and seven months for single-leaf cuttings) before they are ready for planting in the fields. During this time they are stored in a greenhouse where the floor is made of

29. A small greenhouse for hardening rooted cuttings using a Bahnson humidifier

30. Bench grafting. In the middle the stock and scion are prepared for grafting rooting. On the left the graft has been sealed with grafting tape. On the right stock and scion have united and roots have developed

31. Marcotting: root development in treated shoots



concrete and the roof consists of alternating panels of glass and galvanized iron or aluminium sheeting which allow 50 per cent of the incident light to fall on to the young plants. The sides of this greenhouse are open, but protected from wind by climbing plants or coconut leaves. This type of storage of young plants has the advantage of preventing rain from beating on them. Rain falling directly on the leaves can be particularly harmful to young flushes and also washes soil from the baskets. A film of water may cause the young leaves to stick together, effectively sealing the stomata and causing asphyxiation and death of the young leaves. Attack by *Phytophthora* is also common in young plants which are frequently exposed to beating rain. The danger from such attack may be reduced by spraying the young plants with a suitable fungicide, such as Bordeaux mixture. It is, of course, possible to store the plants under a slatted shade which allows 40 per cent to 50 per cent of the total incident light to penetrate. In this case the slats should be fairly narrow (1 inch–1½ inches) to avoid too heavy a drip on the plants.

Similar difficulties may occur in a greenhouse if the plants are watered carelessly. Watering with a hose will have the same effect as beating rain, so a watering-can or a lawn sprinkler is employed. The most common fault is over-watering, which converts the potting-mixture into a water-sodden unaerated mass.

The growth of the plants during storage is dependent on the suitability of the potting-mixture. A good loam with pH value of 5 to 5·5, with adequate amounts of the main nutrient elements present and free from toxic concentrations of minerals, will generally prove suitable without the addition of extra organic matter, provided the structure has not been destroyed by over-watering. If, however, a soil of the above description is not available, and the soil used is neutral-to-alkaline, it is advisable to incorporate some well-rotted compost.

Alkaline soils or soils containing free calcium carbonate are liable to give rise to iron chlorosis in the potted plants, a condition which is extremely difficult to correct. For this reason sea sand containing shells or coral will not be used.

The application of small doses of sulphate of ammonia, 2 grams per basket every 3 to 4 weeks, or spraying with 1 per cent urea, will encourage the growth of the plants.

REVIEW OF PROPAGATION METHODS

The three methods discussed are briefly as follows:

(*a*) Closed-bin propagators with the requisite number of hardeners.

(*b*) Closed-bin propagators in which rooting and hardening are carried out in the same bin, using an organic rooting-medium.

(*c*) Open spray beds.

The first method requires more labour and materials than the others but is, so far, the method in most common use. It is probably the most easily operated, and is the most suitable for small-scale propagation but can also be employed for large-scale production.

The second method calls for more experience for its successful operation.

The open spray beds are much in use for large-scale production where the water supply is not limited.

Water supply is important in deciding the method to be adopted. For example, a closed-bin propagator designed to produce 12,000 plants per annum requires 400 gallons per day while in operation, whereas open spray beds, designed for the same production, require 2,000 gallons per day.

Losses of plants at various stages of propagation and in the field will depend to some extent on the skill and training of the labour employed, the weather, and various factors. There may be about 20 per cent to 30 per cent loss during rooting and 3 per cent to 10 per cent during hardening. Losses in the field may be 10 per cent, but where supervision in the field is lax they may be as high as 30 per cent.

LABOUR REQUIREMENTS

An estate propagator capable of turning out 10,000 plants per annum can be run by four or even three men, if really good labourers are available. The division of labour where four men are employed might be: one to do the daily watering, one to take the cuttings and prepare them for the rooting-bin, and one to pot the cuttings which have rooted; the fourth man is employed to maintain the propagator and look after the nursery.

The amount of labour required will not necessarily be in direct proportion to the number of plants produced, but may depend to some extent on the labour-saving devices employed, as for instance, when perforated pipes are used for watering instead of applying the water by watering-can. Open spray beds are more economical of labour than closed bins.

OTHER METHODS OF VEGETATIVE PROPAGATION

MARCOTTING

By this method rooting is induced on a branch while it is still attached to the tree. It can be employed when a small quantity of

material is required. Standard methods for marcotting are well known, and a technique for marcotting is described by Evans in the *Report on Cacao Research, 1945–1951.*

Grafting and Budding

Both these methods of propagation entail the use of stock and scion, and so have the disadvantage in the field that chupons may grow up from the stock and must be removed frequently. There is as yet not enough experience to show to what extent the cocoa stock may influence the scion. When further work has been done on the subject there is little doubt that the growing of certain clones on suitable stocks will become common practice.

Grafting is difficult with cocoa, and propagating-bins have to be used for some time after grafting. Chip-budding is most suitable for small stocks under ½-inch in diameter, and inverted-tee budding for larger stocks. Dormant buds can be induced to sprout by ring-barking above the bud. Budding can be a quick and economical method of bulking vegetative material when large and vigorous stocks are used.

A system of saddle- or bench-grafting worked out by Evans in Trinidad can be used conveniently where there are facilities for producing rooted cuttings. It is operated as follows: Two cuttings are taken from different trees, one of which is to be the stock and the other the scion. The base of the scion cutting is split and fitted over the wedge-shaped end of the stock. The union is tied with grafting tape and painted with low melting-point paraffin wax. The stock and scion are now treated in the same way as cuttings for rooted cuttings and placed in a propagating-bin.

VEGETATIVE PROPAGATION AT HACIENDA CLEMENTINA, ECUADOR

Mr. Ake Burchardt, in describing vegetative propagation on this estate in 1952, gives some useful information on the procedure adopted and difficulties encountered in working a large plantation.

The permanent nursery of about 6 hectares contains 35,000 cocoa trees, derived from clonal cocoa imported from Trinidad and Costa Rica, and planted at 1 metre by 1 metre spacing. It is shaded with a species of *Inga*, which is satisfactory but needs constant trimming.

The only trouble in the nursery, apart from witches' broom which is controlled, is thrips. The latter has been controlled by applying a mixture of DDT and nicotine sulphate in a soap solution made up as follows:

100 gallons water	1 kg. soap
1 pint 40 per cent nicotine sulphate	2 kg. 50 per cent DDT

500 gallons will suffice for 35,000 nursery bushes.

The nursery is mulched with rice straw and banana stems.

The cuttings used are between 15 to 20 centimetres long with five to six nodes. After the cuttings have been twenty-eight to thirty days in the bin, hardening is effected by lifting the window covering the bin 1 inch per day during the first six days and afterwards to 18 inches. Hardening-off is done *in situ* in the rooting-bins and is completed in seven days.

Great trouble was experienced in the propagators through disease arising from infection by nematodes, and this was followed by fungus attack. Mortality in the bins in the first six days was about 50 per cent and the rooting percentage of the remainder was only 60 per cent. Before the disease appeared there was practically no mortality and the rooting percentage was 80 per cent to 90 per cent.

The situation was saved by having large supplies of material in the permanent nursery, and using a portable steam generator to bring the disease under control.

Hardening-off is completed thirty-seven days after the cuttings have been put in the bin. They are then transferred to beds in a temporary nursery, planted 30 cms. apart, and given a thorough watering. While here they are heavily shaded for the first eight days, the shade being gradually lessened over a period of two months. They are then left exposed until planted in the field, which takes place when they are three to four months old.

Apart from the initial watering, no water is given during the time the plants are in the nursery unless there is prolonged dry weather.

The plants are dug from the beds with a ball of earth attached, and wrapped in leaves of *Heliconia bihai*, in which condition they can be left for fifteen days, if necessary, before planting in the field. Two men on task work can dig and wrap 400 plants in a day.

The chief trouble in the temporary nurseries has been attacks by *Colletotrichum* in the wet season, but these attacks are now controlled by using banana trash around the plants, as the mulch prevents the splashing of spores from the soil on to the leaves during heavy rains. In the case of severe attack, the plants may be sprayed with a solution of 340 grams of Zerlate to 50 gallons of water.

The plants are transported from the temporary nursery to a convenient point in the field by means of tractor-drawn carts which take 600 to 800 plants at a time.

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Chapter VII

THE COCOA PLANTATION (3)

PLANTING AND AFTER-CARE

I. PLANTING IN THE FIELD

Planting at Stake—Planting from Nursery Beds—Planting with Baskets.

PLANTING may be done by setting seed "at stake," or by using plants previously grown in nursery beds or in baskets.

PLANTING AT STAKE

Planting seed at stake may suit conditions where cocoa is easy to establish, such as where it can be economically supervised in the field and where pests which attack young cocoa are not too numerous. When holes have been prepared and filled, two or three seeds are planted per stand, an inch or so below the surface and about three inches apart. When grown, the most vigorous plants are retained and the remainder discarded. An important disadvantage of this system is that there are only two or three plants to choose from, whereas a nursery provides a large choice. Plants growing at stake will require to be surrounded by palm fronds or other shading material for the first few months of their growth, if low shade plants such as *Xanthosoma* sp. have not been established previously.

PLANTING FROM NURSERY BEDS

Where the plants are in nursery beds they should be removed in the morning, being eased carefully out of the soil by pressing a garden fork into the bed to a depth of about nine inches, so as to avoid damage to the tap-root in the process of lifting. Where the soil in the bed is compacted, lifting will be made easier by a gentle watering the previous evening. The object is to allow as much soil to remain adhering to the roots as they will carry, except where there is an admixture of clay, when it is advisable to crumble it away from the

plants. Plants which have recently developed a new flush are left in the bed until the flush has hardened.

It is desirable to plant the seedlings soon after removing them from the bed, but if they have to be transported some distance they can be wrapped in leaves and put in crates or hampers; fifteen to twenty plants to a container make for convenient handling. In the event of unavoidable delay between lifting and planting, the plants may be kept in good condition by putting them in a shaded place and sprinkling them with water every few hours. Where seedlings have to be kept longer than usual before planting, some of the leaves may be removed, but opinion seems to be divided on the value of this procedure.

Planting with Baskets

When planting out in baskets, a hole is made at the planting site deep enough to have the top of the basket at ground level, and wide enough to allow some soil to be rammed firmly around it. The soil around the plant will be levelled off so that it is flush with the ground. If the basket is new, it is advisable to remove the bottom before planting, unless it consists only of a few strands of cane; otherwise it may impede the growth of the tap-root.

Whether the planting is done in prepared sites at stake with unbasketed seedlings or seedlings in baskets, it is extremely important that the soil in the hole is well packed when the plant is installed, and it is advisable to use a ramming-pole for this purpose. Loosely packed soil will compact later and the result will be a saucer effect at ground level; the surrounding soil outside the basket may contract and the soil in the basket dry out. Furthermore, there may be waterlogging around the plant during heavy rains. Also, a plant in loose soil may be more easily blown over. Some planters advocate raising the level of the soil around the plant with a good soil mixture, but this idea is not universally accepted.

Trinidad planters advise that nursery seedlings should reach a height of two feet before planting in the field; it is important that plants be chosen according to their size, health, and vigour of growth, and not according to their age. Successful growers have stressed the need to use sturdy plants and ruthlessly to discard the mediocre and poorly-grown.

II. PROVISION OF SHADE

Temporary Lateral Shade and Ground Cover—Lateral Shade—Ground Cover—Permanent Overhead Shade—Functions of Shade—Practice in Different Countries—Methods of Providing Shade—Type of Shade Tree Required—Shade Indicators—Control and Replacement—Impossibility of laying down Definite Rules.

TEMPORARY LATERAL SHADE AND GROUND COVER

Temporary lateral shade and ground cover have several important functions, including the protection of the soil from the drying effects of the sun, prevention of erosion, and, where the land is not already shaded by high trees, the provision of a suitable environment in which the cocoa can grow. Anyone who has seen attempts to grow cocoa in the open, in any except very humid and cloudy conditions, will appreciate the necessity for providing such an environment from the beginning.

LATERAL SHADE

Tannias (*Xanthosoma* spp.) or eddoes (*Colocasia* spp.) are often used for lateral shade. Several species of bananas are widely used for temporary shade in the West Indian islands and on the continent of America. The bananas may be allowed to remain in the plantation for some time after the cocoa has reached the bearing stage. Some countries are opposed to the use of bananas as they are considered to be heavy feeders. Nevertheless, many cocoa plantations have been successfully established through banana plantations, or have had bananas planted for the purpose of shading the young cocoa. Bananas have the advantage that they grow quickly, their shading capacity can be easily regulated and they provide plenty of material for mulching. They also supply food for labourers and may bring a profitable return to offset establishment costs.

Bananas and shrubs are usually planted in the same lines as the cocoa trees. Where the soil is not naturally rich the growth of bananas can be speeded up by adding compost or manure when planting.

The West African farmer usually relies for ground cover and temporary shade on a variety of food crops, such as cocoyams, maize, cassava, and plantains. Where cassava is planted near the cocoa, there is a danger that the roots of the latter may be damaged when the cassava is being harvested.

Ground Cover

Various leguminous crops have been advocated as ground cover, such as *Pueraria* spp., but they are not widely used, as nearly all of them, with the exception of *Desmodium*, climb the trees and are expensive to control. Shrubby plants, such as *Crotalaria* spp., are in fairly common use as ground cover and lateral shade.

The extent to which economic crops can be used with advantage to provide soil cover and temporary shade for cocoa plantations depends on the soil fertility. There is no doubt that, while the production of large quantities of food crops from the fields in which the young cocoa is planted may bring profitable returns in the first few years, the practice will lower the fertility and is likely to be unprofitable in the long run.

PERMANENT OVERHEAD SHADE

There are few aspects of cocoa-planting which have come in for so much discussion as the respective merits of shading plantations and leaving them unshaded. Although a good deal has been learnt in recent years about shade, not all its functions under varying conditions of sunshine, humidity, and soil are clearly understood.

Functions of Shade

Among the more important functions of shade trees are the protection of the organic matter in the surface layer of the soil from undue exposure to the sun, and the increase of the amount of organic matter by the fall of branches and leaves. The stem and canopy provide shelter from the wind and help to keep the climate immediately around the cocoa (usually referred to as the microclimate) in optimum condition for its growth. The root-system keeps the soil open for drainage and aeration, and helps to remove surplus moisture by means of transpiration through the leaves.

Some types of cocoa trees do not appear to be affected by exposure to direct sunlight, while others are adversely affected. Amelonado cocoa grown over a great part of West Africa will flourish when fully exposed, whereas the type of cocoa evolved from the various introductions into the Cameroons develops a condition known as "leafless twig," when unprotected by shade.

In a rich soil where cocoa grows a luxuriant canopy the ground is well protected both by this and the heavy leaf-fall. In a poorer soil where the canopy is less luxuriant the soil is correspondingly less well protected. There may, therefore, in certain circumstances, be less need for shade on a rich soil than on a poorer soil.

There is no doubt that there will be some competition between young developing shade trees and cocoa trees for soil nutrients and moisture. When the shade trees have reached maturity there will probably be much less competition, and the return in leaf and branch fall may more than compensate for any loss of soil nutrients. Also the shade provided by the canopy of the mature shade tree will slow down evaporation within the plantation. It may be added that one of the advantages of planting in high forest which has been selectively thinned is that most of the trees left for shade will be mature. Posnette and Greenwood, on the basis of their work in the Gold Coast, have suggested that shade, under certain conditions, is responsible for keeping the temperature in the plantation below that in which flushing and growth take place, and so may be indirectly responsible for reducing yield.

It is an interesting fact that in the drier areas of the Gold Coast and, generally speaking, in those most exposed to the severe drying effects of the "Harmattan" winds, such as Northern Ashanti, Afram Plains, the northern part of Togoland, and in some parts of Nigeria, farmers prefer to grow their cocoa without shade. This is probably because there is insufficient soil moisture for both cocoa and shade trees.

PRACTICE IN DIFFERENT COUNTRIES

THE BELGIAN CONGO

In the Belgian Congo the exploitation of the forest for cocoa-planting by careful selective thinning of the trees has been carried out with much greater skill than elsewhere. They are thinned in such a way as to provide the best shade that is possible in the type of forest under treatment. It is necessary at times to have trees whose canopy is too dense or otherwise unsatisfactory, but these are replaced in due course with forest trees of the right type. *Terminalia superba* is popular and seems to fulfil the requirements of a good shade tree. Where there are gaps in the forest and shade is insufficient, secondary forest trees are used to provide it in the interim period until high forest trees can be established.

GOLD COAST AND NIGERIA

The Gold Coast and Nigeria have often been described as countries where cocoa is grown successfully without shade. Nevertheless, in a great many areas of both countries cocoa is easier to establish under shade and it also grows better under shade. The shading may vary from a fairly regular stand of selectively thinned trees to a few large trees left throughout the plantation.

Of recent years, farmers in the Gold Coast have become conscious of the desirability of shade for their cocoa. It is of especial importance where there is a high incidence of capsid, and where the attack is liable to be intensified owing to a break in the cocoa canopy.

Latin America

In certain Latin American countries, where the skies are clouded for a great part of the year, cocoa is usually shaded during the first few years of its life but when the trees reach maturity shade is considered unnecessary.

Ceylon

Van Hall, quoting from Lock, gives an interesting description of shade management in Ceylon. The shade used was *Erythrina lithosperma*, which is widely known in different parts of the world under the name of "dadap," and was preferred in this case on account of its rapid growth, luxuriant foliage, and absence of thorns, and because it could be lopped twice a year. The gist of the description is as follows: Large cuttings of dadap which will develop in a year or two into fair-sized trees are planted between young cocoa plants in the same line. The number of shade trees at this stage will be the same as that of the cocoa plants. When the canopies of the dadaps have developed so that they meet, the thinning process begins and continues until the stands are forty-five feet apart (the cocoa spacing is 15 ft. by 15 ft.), a stage which is reached in about five years after the original planting. At this stage a young dadap-cutting is planted in the square of old dadaps to take the place of these when they have outgrown their greatest usefulness. The cutting down of dadaps, together with the periodic lopping of branches, supplies a great amount of material to enrich the soil.

West Indies

For many years Trinidad has relied on *Erythrina poeppigiana* at higher altitudes, and *Erythrina glauca* at lower levels. In recent years the former has developed a "broom" disease, believed to be due to a fungus, and has died off to a great extent; *E. glauca*, under wet conditions, suffers seriously from a bark-destroying fungus, *Calostilbe striispora*. The disease-ridden shade trees eventually fall, damaging the cocoa trees and causing further serious losses by leaving them exposed. Some clones have been heavily attacked by thrips after the disappearance of the shade trees.

In estates in Trinidad with a tendency to become waterlogged,

this was much less noticeable when a good stand of shade trees was present but became acute after they died.

In Grenada, another country which is described as growing cocoa without shade, the cocoa fields are usually well protected and partly shaded by surrounding belts of trees, such as nutmeg. A considerable number of citrus trees and banana stands are interspersed through the cocoa. Furthermore, many of the fields in Grenada are on steep slopes and, therefore, in shadow for part of the day.

New Guinea

In Australian New Guinea cocoa has been successfully interplanted in coconut plantations, the spacing of the coconuts being 30 ft. by 30 ft., and that of the cocoa 15 ft. by 15 ft. As the cocoa is planted not less than eight or ten years after the coconuts, the palm fronds give suitable shade.

Western Samoa

A system of establishing cocoa in Western Samoa has much to commend it. Cuttings of *Erythrina lithosperma* are stuck in the ground a few feet apart throughout the plantation. This grows ahead of the young cocoa and affords shade and protection from wind, besides enriching the soil with litter. It is kept cut back to a height of three to four feet. When eventually the canopies of the cocoa trees meet, the *Erythrina* is smothered. Permanent shade trees are not used for mature cocoa on many estates in Samoa.

METHODS OF PROVIDING SHADE

As already mentioned, one of the most economical methods of providing shade for a site to be planted in high forest is to thin out forest trees, leaving a sufficient number with a suitable canopy.

The spacing of forest trees kept for shade will depend on several factors, including the spread of the canopy and density of the trees retained, and the rain and the light intensity during the periods when it is desired to have maximum shade. Distances of sixty to a hundred feet apart have been suggested for trees like *Terminalia superba*. It may, of course, be necessary to plant a number of forest trees in those areas where the original distribution does not meet the shade requirement, and it may even be necessary to plant a number of quick-growing secondary forest trees as an interim measure until the slower-growing types have attained the right height.

Secondary forest can provide good conditions for establishing cocoa, if suitable species are present in sufficient numbers. It is in

many respects easier to adjust good secondary forest to provide shade for cocoa throughout the period of establishment than to adjust high forest.

If the cocoa is to be planted where suitable forest trees are not available, and the forest is to be completely felled, it may be possible to plant the shade trees after clearing the brushwood and in advance of felling.

TYPE OF SHADE TREE REQUIRED

The ideal tree for permanent overhead shade is one with a wide-spreading canopy which admits filtered light and broken sunshine. The root system should be such that the tree does not blow over easily and does not compete unduly with cocoa for soil nutrients and moisture. The stems of certain trees are liable to break readily when blown by the wind, and should be avoided. Trees which do well in one country may not do well in another, and some may become tiresome weeds. Where no particular trees have been accepted as standard, a careful study of the forest trees should be made with a view to their trial. Trees with dense foliage are unsuitable. Deciduous trees, which shed their leaves in the dry season, are better than evergreens, as they provide a check on transpiration and the leaf fall will provide a ground cover in the dry period. Trees which have no thorns on the stems are also desirable, as they can be climbed when it is desired to cut them back or trim the foliage.

In the past, leguminous trees were considered best, as much importance was attached to the value of the nitrogen they supplied. While the presence of nitrogen may have been of importance in certain soils, cocoa has grown well in Africa in the absence of leguminous trees, and in forest where non-leguminous trees predominate.

SHADE INDICATORS

Grass growing within the plantation can usually be regarded as an indication of insufficient shade. In Trinidad, luxuriant growth of *Zebrina pendula* (called "cockroach grass" though, of course, it is not really a grass) is regarded as an indication of good shading conditions.

CONTROL AND REPLACEMENT

In the past there was probably too great a tendency to regard "permanent" shade as really permanent. Where the particular trees used would respond to pollarding, the height and size could be con-

trolled by this means. Experience over many years of cocoa-growing in countries where shade is necessary suggests that, while permanent overhead shading of cocoa is desirable, it is highly important from time to time to replace the trees with new ones or with trees of another species.

IMPOSSIBILITY OF LAYING DOWN DEFINITE RULES

Overhead shade for growing cocoa is the rule in most countries. It would, however, be idle in the present state of knowledge to say categorically where and how shade should be used. Attempts to grow cocoa without shade in some countries have in the past led to disaster. Until such time as scientists are able to give convincing explanations of the various functions of shade the planter will have to take local successful practice as his guide. It may be accepted, as a general rule, that all cocoa in the young seedling stage must be shaded and that young cocoa benefits from shade until it approaches or reaches maturity, when there is mutual shading of the cocoa trees where they are closely planted.

III. WINDBREAKS

Necessity for Protection from Wind—Best type of Windbreak—West Indian Practice.

Windbreaks must be planted after careful study of the prevailing winds. Cocoa trees react unfavourably to the cold or drying winds which may blow at certain seasons of the year, and they also suffer when exposed to periodic gales from the sea. The provision of windbreaks is as necessary under certain conditions as the provision of shade or drainage. In West Africa, large areas of cocoa died off when the forest which protected the cocoa from wind was removed in the course of annual food-crop farming.

In the normal course of clearing the forest for planting, the underbrush is removed, and even where shade trees are planted there may be conditions where, just above ground level, there is little to obstruct drying winds from sweeping through the plantation. In conditions like these a windbreak is of especial value and it can have an important function in maintaining atmospheric humidity and an equable temperature.

Best Type of Windbreak

A barrier which is permeable and allows the wind to filter through, such as a strip of woodland, makes the best windbreak. It may take the form of a strip of forest trees, fifty feet to a hundred feet or more wide, or a hedge or row of trees. It should in any event not be so dense as to form an "impenetrable wall," over which the wind will glide with its violence only partially diminished.

If the plantation to be established is surrounded by forest, a strip may be left, which can be treated so that there is a maximum stand of economic timber trees of different ages. As these mature they can be removed from time to time and replaced by new ones. The choice of trees left to protect the plantation can be decided best after discussion with people of local knowledge or consulting the Forestry Department.

West Indian Practice

In Grenada and Trinidad some estates have provided windbreaks with trees forming two storeys, the upper one being formed by mango (*Mangifera indica*) or galba (*Calophyllum antillanum*), and the lower one, which fills the spaces between the trunks of the taller trees, by *Hibiscus* or *Dracaena*. The latter forms a dense hedge which grows to a height of twenty feet or more. Other trees used in these two countries as windbreaks are sapodilla (*Achras sapota*), West Indian mahogany (*Swietenia mahagoni*), cloves (*Eugenia aromatica*), Barbados almond (*Terminalia catappa*), and cashew nut (*Anacardium occidentale*).

It is not always sufficient to provide windbreaks around the outside of large plantations. It may be necessary also to have windbreaks within them to temper the wind in sections which would otherwise be unduly exposed.

It is important that the trees used as windbreaks should be deep-rooted and not easily blown over. In deciding the extent to which trees of economic value for their timber or fruit should be chosen, first consideration will have to be given to their suitability for providing shelter, and the avoidance of those which may attract pests.

IV. AFTER-CARE

Attention required in Early Stages—Later Stages—Pest and Disease Control—Shaping and Pruning—Removal of Chupons—Shaping in relation to Spacing, etc.—Rooted Cuttings—Use of Chupons—Manuring.

The operations involved in after-care of newly-planted cocoa vary greatly with the climate and the methods adopted in growing it.

ATTENTION REQUIRED IN EARLY STAGES

Light hoeing around the young seedlings encourages the spread of the feeding roots. The extent to which weeding is required will depend on the amount of shade in the plantation and on the local rainfall. It is important to emphasize the necessity for weeding by hand the area immediately around the young plants, in advance of the general cutlassing of the weeds throughout the farm. Labourers swinging cutlasses are very liable to sever the stems of young plants or injure them to such an extent that they become diseased and die. In this way many trees in plantations have been lost in the first few years of establishment, and, as complete supervision of the labour is impossible, the only safeguard is weeding by hand in the immediate vicinity of the cocoa.

During the twenty-four to thirty months after planting, some young trees will have become casualties, and these will have to be replaced. After this time it is not considered economic to replace them. Shade will have to be trimmed back and adjusted so as to allow the proper amount of light to reach the cocoa, and missing shade trees must be supplied.

Removal of chupons and shaping of the young cocoa trees will need particular attention during the first few years.

DRAINS

Drains will require to be cleaned and the drainage system enlarged according to the needs of different parts of the estate. The fork is a better implement than the spade for cleaning drains as labourers are inclined to smooth over the sides of the drains with the spade and thereby impede the flow of water into the drain. The débris from the drains will be left in heaps for a time to decay before it is applied to the trees. Where such débris is highly acid it is improved by having some lime mixed with it.

The road system will be extended, and attention to culverts and road surfaces will be part of the general development of the plantation.

32. Young cocoa established under forest trees which have been selectively thinned, Belgian Congo

33. Young cocoa growing in the shade of bananas, Grenada

34. A mixed plantation of coconuts and cocoa in New Guinea

35. A cocoa plantation in Western Samoa with ground cover of Dadap (*Erythrina lithosperma*)

36. Windbreaks on River Estate, Trinidad: (*Left*) *Dracaena* forming a tall dense hedge. (*Right*) West Indian Mahogany (*Swietenia mahogani*)


37. Cocoa trees growing beneath shade of the Umbrella tree in the Belgian Congo

38. Young cocoa growing in partly thinned jungle, Malaya

39. Young cocoa trees growing under thinned forest shade in the Belgian Congo

40. A young cocoa plantation at Keravat, New Britain. Shade trees are *Leucaena glauca*


LATER STAGES

Except in those countries where cultivation is common practice, such as Grenada and Ceylon, deep-forking or digging of the soil near the plant is not recommended. Where deep cultivation is the rule from the beginning, the plants develop a deeper root system, but sudden deep cultivation of a plantation previously uncultivated would be disastrous. The periodic application of heavy dressings of farmyard manure or compost is at present confined to a few countries only. The average planter would not resort to manuring unless he had satisfied himself by tentative experiment, or unless properly laid-out experimental trials indicated that manuring was profitable.

PEST AND DISEASE CONTROL

Control of pests and diseases will take a certain amount of time. Rats, monkeys, squirrels, and parrots can all be troublesome where they are numerous. The planter may require to have recourse to trapping, shooting, and poisoning, in order to reduce their number. Beetles which bore into the stems or cut the bark of the young plants will have to be hand-picked or sprayed. Black pods resulting from *Phytophthora* fungus should be removed early to reduce spread. Cankered wood will have to be removed, and wounds and exposed areas of the stem treated with tar or paint. Where witches' broom is present, it must be removed as frequently as recommended by authorities who have made careful studies on the spot.

Mere sanitation alone may not eliminate pests and diseases, but it is accepted that a high standard of sanitation greatly reduces the incidence of many of these and is more economic than relative neglect.

SHAPING AND PRUNING

The main objects in pruning are to remove unwanted growth and train the trees to the desired shape. The aim in shaping will be to produce a well-balanced framework on which the fruit may be borne. The number of branches to be left at the point of ramification or jorquette is important. Some advocate having as many as four, while Dutch planters prefer three or even two. The final framework will, to a great extent, be built on these, and the general plan will be to fill the space occupied by the trees with a balanced development of branches.

Excessive Pruning

The various methods and systems of pruning cocoa have as yet had little or no attention from the scientist, so that the only guidance available is the experience of successful planters. The skilful use of the pruning-knife to regulate vegetative growth will induce greater crop yield, but rash and unskilful pruning can give the trees a severe set-back. Excessive and sustained pruning and cutting back may bring about stagnation of growth with consequent reduction in yield, and induce abnormal chupon growth from the main stem. It may also induce excessive flushing and make the tree more susceptible to insect attack.

Frequency of Treatment

Some planters favour undertaking main pruning operations on mature trees at intervals of two years, while others are in favour of annual treatment in the dry season. Yet other experienced planters consider that light pruning should be performed annually, and that heavy pruning should be done only once or twice in the life-time of a tree, or when the trees have been neglected and fail to produce new wood. Certain planters adopt the plan of careful pruning of 25 per cent of the plantation annually.

Removal of Chupons

Some cocoa trees are prone to produce shoots from the main stem or from branches, which are variously known as chupons, watershoots, suckers, or gourmandisers, and these are best removed while they are still tender.

Shaping in Relation to Spacing, etc.

A tree with a somewhat spreading habit is preferable to one with an upright habit, especially where there is the danger of fungi being carried from the pods above to the pods below. Where trees are close together, fan branches will have to be cut back in order to prevent overlapping and permit access to the plantation between the rows. The pruning and shaping of trees which are planted 8 ft. by 8 ft. or 9 ft. by 9 ft. will obviously differ from those planted, say, 15 ft. by 15 ft. Where conditions are humid and the sky is much overcast for long periods it may be desirable to open the canopy by thinning, to admit light and discourage the growth of fungi. Trees growing in a moist, loose soil may become top-heavy and fall over during a storm unless the canopy is thinned.

Neal Fahey of Trinidad recommends light pruning and the removal of thin and whippy branches in plantations at higher levels

on exposed hillsides; this may also apply to trees in drier areas. He maintains that trees growing in a "parasol" shape are best suited to dry conditions.

ROOTED CUTTINGS

The shape of the young plant grown from seed differs from that of a plant from a rooted fan-cutting. The treatment of the fan-cutting in the early stages of its growth requires somewhat different handling from that of the seedling, although the ultimate aim is similar. A fan-cutting branches at a low level, with the result that at close spacing it is difficult to walk through a field of clonal cocoa. Sooner or later a fan-cutting will give rise to a chupon from the base. Some planters remove these but others encourage them, cutting off the fan-branches of the original rooted cuttings when the chupon is old enough. This will eventually result in a tree shaped like a normal tree grown from a seedling.

Apart from the consideration of whether the tree starts life as a seedling or a rooted cutting, the habit of growth of certain trees, such as Amazon types and certain Trinitarios, has to be taken into account.

USE OF CHUPONS

In plantations which have been neglected for a time chupons will grow up and replace the original stem, the latter rotting away and disappearing. They are often used to rejuvenate old cocoa trees, in which case a chupon issuing from the base of the tree is chosen and earth is piled up against the base of the chupon to induce roots which will anchor it firmly in the soil. If a chupon is selected higher up the original tree stem, it will fall away when the latter rots.

Opinions vary as to the number of new stems that should be grown from chupons at one stand. Some prefer one, others say that two stems at the same stand will yield more cocoa than one.

MANURING

Manuring of cocoa as a general practice is only common in a few parts of the world. Ceylon uses both farmyard and artificial manure, whereas some planters in Grenada and Trinidad apply mulches.

Experiments with artificial manures have been made in some West Indian islands in the past, notably at River Estate, Trinidad, belonging to the Cocoa Research Scheme. In the past these tests were carried out with seedlings derived from hybrid material, and

although some of them gave interesting results they are not so reliable as those laid down with cocoa material which has been vegetatively propagated. A comprehensive group of manurial experiments has recently been laid down where rooted cuttings have been used. It is expected that these experiments will give more conclusive results than any attempted in the past.

Much, however, remains to be done in testing the reaction of cocoa to various artificial manures. The success of systems of artificial manuring in one country should not, however, be taken as a guide in another where conditions of soil and climate are different.

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Chapter VIII

THE COCOA PLANTATION (4)

PREPARATION OF THE CROP FOR MARKET

I. HARVESTING

Precautions to be observed—Labour required.

In countries with a well-defined dry season of several months the main harvest usually begins at the end of the wet season and continues in the first few months of the dry season, with possibly a minor harvest during the first months of the following wet season.

PRECAUTIONS TO BE OBSERVED

Harvesting consists of picking and breaking the ripe pods, removing the beans and transporting them to the fermentary. Labourers new to the work may require some instruction on how to distinguish ripe pods, but after some practice they can do so quite readily. Most pods assume a distinctive colour when ripe. For instance, green-podded Amelonado turns yellow, and red pods usually turn an orange or near-orange colour. These changes are slow and the pod will remain in a suitable state for harvesting for two or three weeks.

The fruit is borne on cushions on the stem of the tree. These may cease to bear if damaged, so it is most important that the harvesting tools should be sharp and so shaped that the cushions cannot be injured, as a damaged cushion can provide a point of entry for fungi. In many parts of the world the machete is the usual harvesting implement, but a sharp knife is better, and very careful planters use secateurs. A long-handled knife which can cut with both an upward and a downward thrust is required for pods above a certain level. The pod stem should be cut close to the tree, the thickened jointed portion being left attached to the cushion. This stump drops off later, leaving a well-healed scar which is impervious to fungi.

It is important that only ripe pods be picked; under-ripe pods may not have sufficient sugar in the pulp for successful fermentation, which is the next operation. On the other hand, over-ripe pods tend to become dry, and germination of the beans may be induced.

It must be emphasized that beans from diseased pods should not be fermented with the healthy ones. Very often such beans are infected with mould, which may cause weakening of the testa, and allow other moulds to enter. Beans showing mould are particularly objectionable to manufacturers.

LABOUR REQUIRED

Labourers employed on harvesting should be on "daily pay" rather than on "task" or contract, as there is the possibility of the trees being damaged and of unripe pods being harvested, if the operation is rushed.

The number of labourers naturally depends on the number of trees and the heaviness of the crop. Neal Fahey of Trinidad suggests the following division of labour for harvesting: a gang in charge of an overseer would consist of 5 men picking; 2 to 6 gathering pods into small heaps; 3 to 5 collecting the small heaps into large heaps. There are also women who usually lift the pods by sticking the point of a light cutlass into them and flicking them into a basket. One man is engaged in cutting the pods open, and four women extract the beans, generally using a wooden spatula, because when large quantities of beans are dealt with, the juices from the fresh beans may be "hard on the hands."

The pods are usually opened by cutting the husk with a knife or machete, but by this method a proportion of the beans may be damaged and rendered susceptible to attack by insects and mould. It is preferable to open the pods with a wooden mallet or by striking two pods together.

It is common practice to harvest one day, and break the pods and transport the beans to the fermentary on the following morning.

II. FERMENTATION

General Observations — Purple Beans — The Fermenting-house — Fermenting-boxes — The Fermenting Process—Observing Progress—Causes of Unsuccessful Fermentation—Equipment: Cleanliness—Fermentation of Different Types of Cocoa—Handling Small Quantities.

GENERAL OBSERVATIONS

It is most important to remember that it is only from properly fermented beans that the full chocolate flavour can be developed by roasting. The main object of fermentation, therefore, is to develop the "precursors" of chocolate flavour in the beans.

Success depends on several factors—the temperature developed in the fermenting-boxes or heaps, the duration of fermentation, the aeration of the beans and the micro-organisms present.

In the early stages the bean dies and enzymes which play an important part in the process are released. As fermentation proceeds most of the pulp which surrounds the beans disappears and the seed coat becomes loosened from the kernel. This is of importance since the shell has to be separated from the nib in the course of manufacture. The good qualities of cocoa are enhanced by proper fermentation, but they can be destroyed if this process is over-prolonged or carelessly performed. Insufficient fermentation of Amelonado cocoa results in purple and slaty beans and these are practically impossible to manufacture into good chocolate, being bitter and astringent as well as lacking in chocolate flavour.

PURPLE BEANS

In recent years an increasing proportion of under-fermented purple beans has come on the market. They vary from bright purple with a "cheesey" texture to dull purple with an open texture like that of a well-fermented bean.

A high proportion of purple beans may result if the beans have been fermented for too short a period, if the fermenting mass does not reach or is not maintained at the right temperature, if unripe beans are included in the mass, and if the drying after fermentation is too rapid.

Some producers try to reduce the number of purple beans simply by fermenting for a longer period, but this may easily lead to over-fermentation.

While it is usual to expect high-quality manufactured chocolate from beans of a good brown colour, brown beans can be produced by methods other than fermentation. Fermentation, however, is the only way of producing the "precursors" of the true chocolate flavour, and dependence on visual examination alone is not a sufficient test of good preparation.

THE FERMENTING-HOUSE

On organized plantations fermentation is carried out in properly designed and equipped buildings, though well-fermented cocoa can be produced by more primitive methods.

The fermenting-house is usually an oblong building, and may be some 24 ft. long by 21 ft. wide, with a row of fermenting-boxes on each side, and a passage down the middle. A wide space between the eaves of the roof and the top of the wall on the lee side of the house permits a free movement of air and the escape of gases emanating from the fermenting cocoa.

A substantial house for the process would consist of concrete walls and a roof of aluminium sheeting. As the juices which run off from the fermenting cocoa are corrosive, it is desirable to have the fittings made of wood or other resistant materials. Flooring will last longer if the tiles and cement are acid-resisting.

FERMENTING-BOXES

Fermenting- or sweat-boxes are usually of inch-thick planks, and so constructed that the planks fit into slots so that they can be slipped out when it is desired to transfer the cocoa from one box to the next, or to vary the size of the box, or to wash the planks. Where nails are used, they are inserted in such a way that they do not come in contact with the beans as these may become stained by contact with metal. The boxes should be made of durable wood, such as *Chlorophora excelsa*, *Carapa guianensis*, and *Hieronyma caribaea.* Three-eighth-inch holes about six inches apart in the bottom of the box allow the liquid to drain away in the process of fermentation.

The dimensions of the boxes may range between 3 ft. deep by 5 ft. by 4 ft. (or 1 m. deep by 2 m. by 1 m.) and 3 ft. deep by 9 ft. by 6 ft. It is generally accepted that the depth of fresh cocoa should not exceed three feet for good fermentation, and as wet cocoa

weighs about 50 lb. per cubic foot, a box 5 ft. long by 4 ft. wide would take some 3,000 lb. of cocoa. It is difficult to ferment quantities of less than 300 to 400 lb. of wet cocoa, but quite large amounts can be fermented at one time in containers of a suitable size, provided there is not too great a depth of cocoa.

Much labour will be saved if the house is built lengthwise down a steep slope, with the fermenting-boxes arranged in steps down the side, the top of each successive box being level with the bottom of the preceding one. The cocoa can thus be easily transferred from one box to the next by simply removing a few planks from the front.

The number of fermenting-boxes and the capacity of the drying facilities should be sufficient to cope with the crop of an estate at the time of maximum harvest.

THE FERMENTING PROCESS

The routine of fermenting cocoa is similar in most countries. The fresh cocoa is put in the boxes which may be lined with banana leaves, and the mass is covered over with further leaves to retain the heat. After forty-eight hours, by which time the mass should have developed sufficient heat (not less than 47° C.), it is mixed and turned into another box. The second turning may take place after twenty-four hours if the fermenting mass is large, say over 10 cwts. During turning, the temperature of the mass will drop considerably, so when dealing with quantities of less than 10 cwts. a period of forty-eight hours should elapse between turnings. The turning is repeated daily or on alternate days until the cocoa is fermented, which may be six (but not more than eight) days from the start. Heat is produced in the early stages of fermentation by the action of micro-organisms which can live in the absence of oxygen, but as the temperature rises these are replaced by others which require air. The temperature in the fermenting-box should reach and be maintained at 47° to 51° C. One reason why the depth of cocoa in the fermenting-box should not exceed three feet is that there must be adequate aeration at the second stage.

The boxes should be sheltered from cool winds which would delay or prevent the proper rise in temperature. The work of mixing the beans and transferring them from one box to another should be carried out as quickly as possible to prevent undue cooling of the mass, with subsequent slowing-up of fermentation. Mixing must be done thoroughly when changing from one box to another if an even fermentation is to be achieved.

OBSERVING PROGRESS

The development of fermentation can be roughly tested throughout the period. The temperature at different stages can be estimated by plunging the arm into the fermenting mass, and the progress of the operation can be judged by cutting through a few beans, noting the degree of change in colour, the gradual separating out of the laminae of the cotyledons and the change from a bitter to a milder taste. The deep blue or purple of the fresh Forastero gradually changes to a lighter colour, and when fermentation is complete the kernel is readily detached from the seed-coat and the kernel itself can be easily broken up. When dry, the well-fermented bean will show an even break if both ends are held between the fingers and it is snapped through the middle.

CAUSES OF UNSUCCESSFUL FERMENTATION

There are occasions when the fermentation of a consignment of cocoa may go wrong. Some of the predisposing factors are the presence of over-ripe or under-ripe beans, or beans affected by *Phytophthora*, beans which have dried out by being too long in the pod after harvesting, or which have got wet during a rainstorm while being transported from the field.

If the season changes from being humid and warm to being dry and chilly at night, the period of fermentation may have to be slightly extended.

EQUIPMENT: CLEANLINESS

Wooden shovels have been much used in the past to transfer cocoa from one box to another, as the sharp edge of the ordinary metal shovel would damage the beans. In Western Samoa, square-mouthed metal shovels with a strip of steel welded on to the lip are found to be satisfactory, especially if thoroughly washed after use. During the operation of turning and mixing, the cocoa must be picked over, and foreign matter, the placenta, and diseased beans which may have found their way into the mass, must be removed. The fermenting-boxes must be washed and scrubbed from time to time.

FERMENTATION OF DIFFERENT TYPES OF COCOA

Fermentation of Amelonado or Criollo cocoas is carried out on similar lines, the former taking anything from six to eight days, and the latter two to five days; but the even and satisfactory fermentation of mixed samples of Trinitarios, and of hybrids which tend variously towards Amelonado and Criollo types, is difficult. It is necessary to keep Amelonado and Criollo types apart during harvesting and ferment them separately. In a number of countries where the first introduction was Criollo, followed later by Forastero, the mixture is often uneven. The only thing that can be done here is to compromise and find out by experiment what type of fermentation is best suited to the greater bulk of the particular mixture being dealt with. In the course of time, by means of vegetative propagation and later by breeding, the mixed cocoas of to-day may be converted to a high-grade uniform type.

HANDLING SMALL QUANTITIES

There are occasions when harvestings are not sufficiently large to undergo fermentation by themselves. These small lots should be put in a container which is well insulated to enable the small mass to generate the necessary heat. They should not be added to larger parcels of cocoa which have already undergone partial fermentation, but should be fermented by themselves throughout. When dealing with these small quantities it will be necessary to stir and mix the mass in the same container, as less heat will be lost in this way than if the cocoa is transferred to another container for the purpose of turning.

III. DRYING AND STORAGE

Sun-drying—Artificial Drying—Cocoa-drying on Lukolela Estates — Types of Driers — Slow Drying — Testing for Dryness—Storage.

SUN-DRYING

In countries where the main harvest takes place chiefly in the dry season it is usual to dry cocoa in the sun. The beans are transferred from the fermenting-boxes and spread on drying-floors or trays. In order to expose them fully to the sun, they are raked over with a wooden rake—usually a piece of board fixed on a long handle.

Where the midday sun is strong, it may be necessary to cover the cocoa with mats for about two hours in order to prevent too-rapid drying and crinkling of the seed coat. Mats are also usually held in readiness for spreading over the cocoa in case of rain.

A convenient arrangement for getting the trays under cover at night or during rain-showers is to have them fitted with wheels to run on rails, so that they can easily be pushed under a roof when necessary. Alternatively, a roof can be arranged so that it slides to-and-fro over the trays.

During the time the cocoa is drying it is continually picked over to remove foreign matter and immature and defective beans, and to separate beans which are sticking together.

The period of sun-drying may take from one to two weeks, depending on the weather. The depth of the beans on the drying-floor should not be such as to make the process of drying unduly protracted. A rough idea as to the drying-space required may be gained from the fact that 112 lb. of wet cocoa requires $5\frac{1}{2}$ square feet of drying-space. In humid climates it is desirable, at the start of the operation, to spread the beans in a thin layer on the drying-floor, and to increase the thickness as the cocoa becomes drier.

Where concrete floors are used for drying they are covered with mats to insulate the beans from the cement, and also to make for better drying. It is inevitable that in gathering up the cocoa from a concrete floor a certain amount of grit will be swept up also, and this in any form is extremely objectionable. Although machinery is used to extract foreign matter at an early stage in manufacture, there is the danger that some may be incorporated in a foodstuff and also that the machinery may suffer damage.

ARTIFICIAL DRYING

Where conditions are suitable a combination of sun-drying and artificial drying may be applied. Most people favour at least one day of sun-drying before artificial drying begins.

A plant for drying cocoa artificially may consist of a building where the hot air is supplied from underneath through a perforated floor, or it may be a container which rotates while a stream of hot air is applied to the cocoa, as in the case of the McKinnon or Gordon driers.

McKinnon driers are extensively used in Samoa and in parts of New Guinea, and both McKinnon and Gordon driers are in use in certain islands in the West Indies.

COCOA-DRYING ON THE LUKOLELA ESTATES

The Lukolela Estates in the Belgian Congo have arrangements for fermenting and drying which are interesting in that they represent the routine followed in a large and carefully supervised organization. The cocoa is an Amelonado type, and the drying process is partly sun-drying and partly artificial drying.

The drying-house is a long building at each end of which there is an outside furnace connected with lines of piping which run on floor level to a chimney at the opposite end. The obvious virtue of having two furnaces, one at each end of the building, is that it gives a better distribution of heat than where the furnace is at one end only.

Two sets of rails run from outside right across the full width of the inside of the building, each at different levels, the lower set being $5\frac{1}{2}$ feet above the hot pipes. Each set of rails takes ten trays, and the drying-house can accommodate eighty trays at a time. There are air outlets on the ridge of the drying-house.

A drying-tray is $12\frac{1}{2}$ ft. long by $8\frac{1}{2}$ ft. wide and 8 in. deep, and the base consists of a wire mesh which prevents the beans from dropping through. For the first day of sun-drying, the wire base is covered with a mat so that the fresh cocoa does not come in contact with the metal, and by evening the mat is removed, as being no longer necessary.

The following are the consecutive steps taken in the processes of fermentation and drying at Lukolela. The pods are picked on Monday. On Tuesday they are broken and the beans carried to the fermentary. The fermenting-boxes are arranged in batteries of seven. The cocoa is fermented for about seven days, but remains for forty-eight hours in the first box. This provides a spare box for fresh cocoa on the following day and makes for more economical use of the equipment. The cocoa is put in the fermenting-box at 2 p.m. and

after going through the usual treatment is removed at 6 a.m. on the following Tuesday. It is spread thickly on a large wooden tray, rubbed over to remove adhering matter, and then placed on the drying-tray in a layer 2 cms. deep.

By the second day of drying, the depth is increased to 4 cms., and on the third and last day to 8 cms. The cocoa is sun-dried in the daytime, as far as possible, and the trays are pushed into the drying-house at night.

The usual time taken at Lukolela, when it is possible to combine sun-drying and artificial drying, is three days. The plant is capable of turning out 10,000 lb. of dry cocoa per day.

The cocoa from Lukolela gets a premium for its good quality.

TYPES OF DRIERS

The firm of Huileries du Congo Belge, which in recent years has taken up cocoa-growing in the Belgian Congo, has set up a plant for artificial drying which is worked on a different principle from those used in the past. This is known under the name of the Turberien-Trockner drier, and is made by the German firm of Buttner-Werke. The principle is basically simple. The plant consists of a large vertical cylinder into which a stream of dry air is driven. The trays of freshly-fermented cocoa enter at the top, move down a spiral, and emerge at the bottom. The drying plant of this type installed at the H.C.B. estates at Mokaria is designed to dry nine tons of cocoa in twenty-four hours. A similar plant installed on an estate in São Tomé is said to be working satisfactorily.

The principle embodied in this apparatus has been applied to the drying of agricultural products in temperate climates for some considerable time but has only recently been used for the drying of cocoa.

The Martin (hot-air) drier has also given good results. Three of these driers have been built on the New Zealand Reparation Estates in Western Samoa (see diagrams). The largest Martin drier has a drying-platform which measures 45 ft. by 25 ft. and can take a maximum load of 11,200 lb. of fermented cocoa spread out in a layer two inches deep. It takes twenty hours to dry the cocoa fully on the Martin drier, though it should be mentioned that on these estates the cocoa is washed before drying.

Slow Drying

Whichever method of drying is adopted, there is no doubt that the drying processes should not be hurried, and this applies particularly to artificial drying. After drying, the cocoa is allowed to cool before bagging.

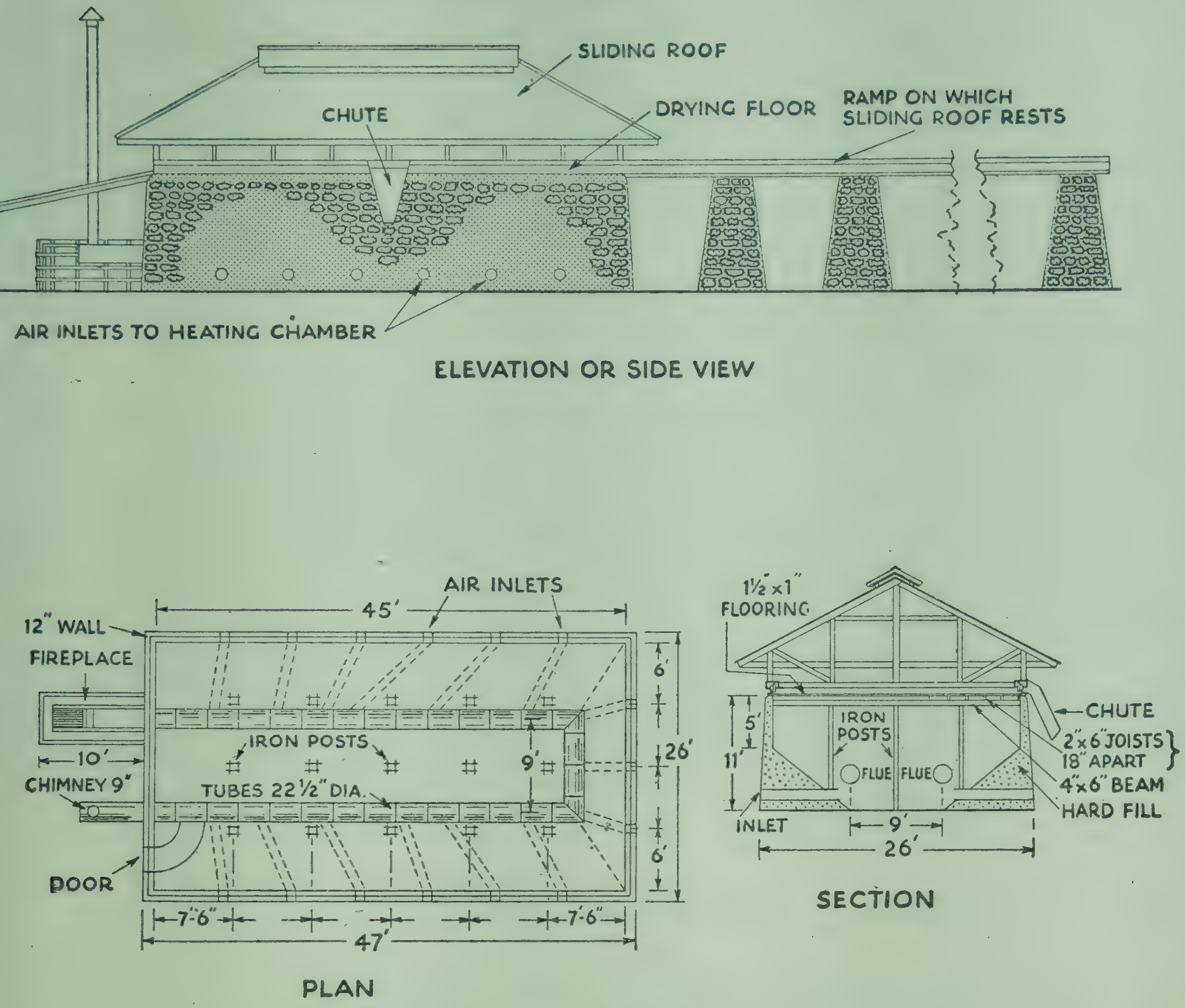

FIG. 4

THE MARTIN DRIER

Testing for Dryness

A simple and practical method of testing for dryness is to take a handful of beans, press them hard, and if the shells crackle the sample is dry. A more accurate test is to cut through the bean with a knife, when it will be found that the cotyledons will separate easily if dry. The moisture content of dried cocoa should be about 6 per cent and should never be as high as 8 per cent.

Cocoa beans undergo a loss of between 55 per cent and 64 per cent in weight in the process of fermenting and drying.

When the beans vary considerably in size, grading into two or three sizes may be desirable. Where this has to be done on a large scale, power-driven mechanical graders are used.

STORAGE

Cocoa readily absorbs flavours and aromas, so drying equipment used for other crops, such as copra, is to be avoided. When certain simple forms of driers are used it is essential that the smoke from the driers does not come in contact with the cocoa at any stage of the drying process. Similarly, during storage cocoa must be kept apart from other products the flavour of which it would readily absorb. If the floor on which the cocoa is to be stored is of concrete, wooden dunnage, six inches thick, should be used to insulate the cocoa from the floor.

The fermented, dried cocoa beans are the "raw cocoa" of commerce and are bagged and shipped in this condition for manufacture. Most estates do not store their dry beans for any length of time but transport them for sale or shipment within a few weeks of drying.

The following are standard weights of full bags in certain countries:

	lb.
Gold Coast and Nigeria ..	140
Bahia	132
Trinidad and Grenada ..	165 or 200
Ceylon, Java, and Samoa ..	112

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See also Appendix V: *Cocoa Fermentation.*

1. Cocoa harvest in West Africa. Pods being opened with a small machete

2. Building a fermenting heap; the beans are being placed on plantain leaves, West Africa

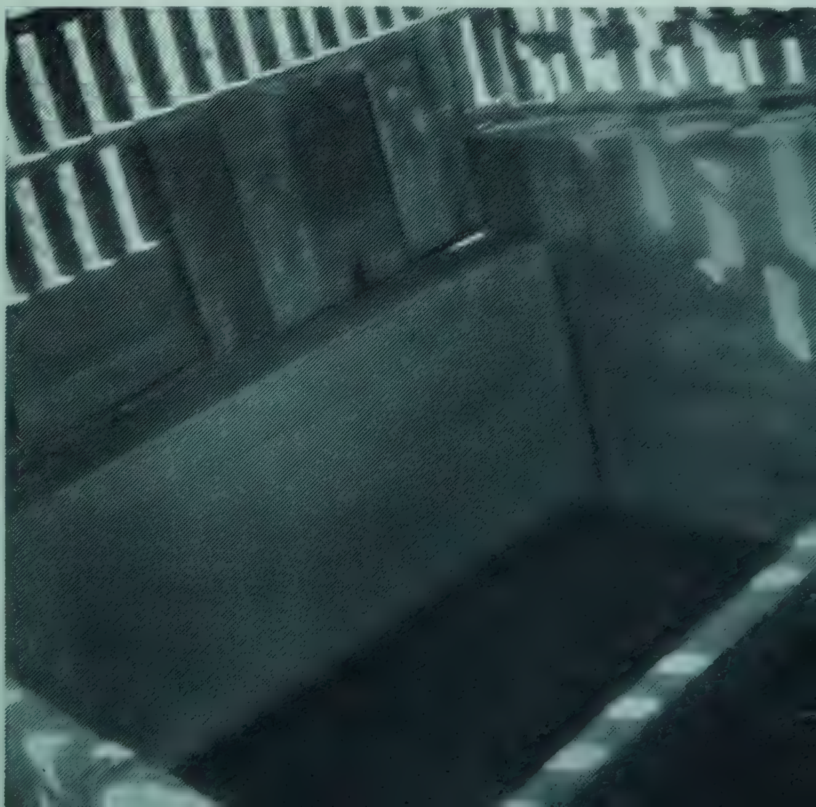
43. Covering a completed heap with plantain leaves which are held in place with pieces of wood, West Africa

44. Cocoa drying on mats in the Gold Coast

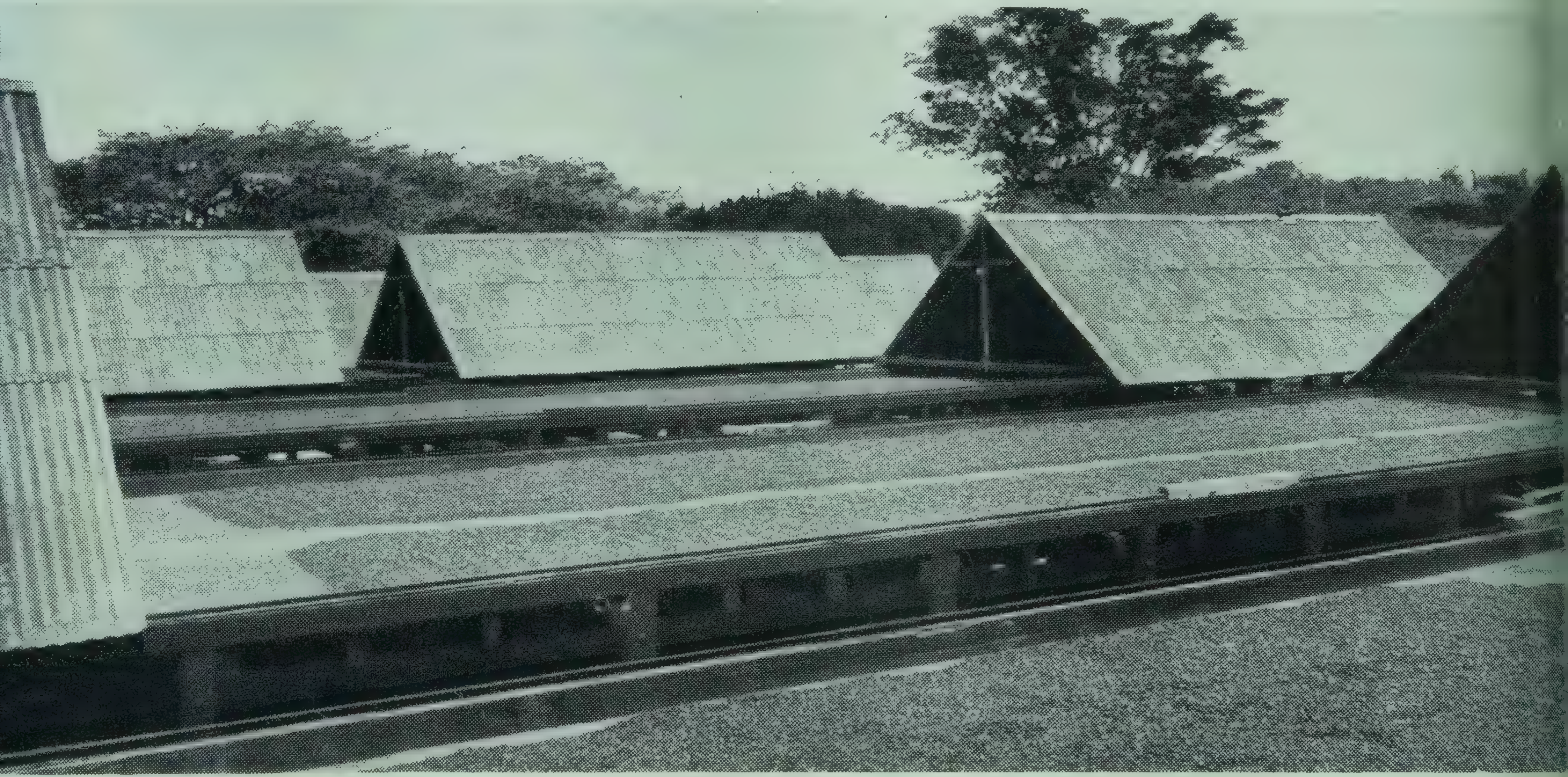
45. Fermentary, Venezuela

46. The inside of the fermenting-house shown in Fig. 48, showing the seven sweat boxes

47. A typical fermenting-box, Grenada



48. A fermenting-house in the Belgian Congo. It is built on a slope to reduce labour in handling cocoa



49. Drying-sheds on an estate in Trinidad. The roof of each shed is in two parts which run on rails

50. Trays outside drying-house at Lukolela, Belgian Congo

Chapter IX

PEASANT COCOA CULTURE IN WEST AFRICA

History — Methods of Farming and Planting — Labour Required — Shade — Harvesting, Fermenting, Drying — Diseases and Pests—Pros and Cons of Peasant Culture—Improving Peasant Culture—Some Problems of Replanting and Rehabilitation—The Place of Cocoa in a Peasant Economy—The Future of the Peasant Industry.

A GREAT deal of the cocoa of the world is grown by peasants and peasant communities. The development of cocoa planting in West Africa is, on the whole, different from that by peasants in other countries. In West Africa planting in the early years was mainly on small farms on communal land, but, later, enterprising and independent Africans launched out and made their own farms on a larger scale.

Because of the importance of the West African development, and because there is nothing in other countries quite comparable with it, this chapter discusses peasant culture in West Africa only.

The Gold Coast produces the greatest quantity of cocoa. The original introduction of very small amounts, the rapid rate of planting, the slowing down of output after a time, and the onset of disease, has been the pattern of development of the peasant cocoa industry which has been repeated in the other West African countries, such as Nigeria and the Ivory Coast. The reason why similar systems of culture were adopted by them is not because of the example set by the Gold Coast, but because it is the method which fits most easily into the farming systems of the forest zone.

Before the days of cocoa-growing in the Gold Coast, the chief agricultural exports were rubber and palm oil, and it is interesting to note that in the eyes of the African farmer these faded into comparative insignificance in proportion as cocoa gained ground.

HISTORY

It is not very certain when the first introductions were made but there are records of attempts in 1868 to grow cocoa introduced from

Central America. About 1878 there was an introduction by a labourer returning from either Fernando Po or São Tomé, and there is a reliable record of cocoa pods being introduced from São Tomé in 1886.

Customs figures show that from 1892 to 1896 the annual export of cocoa from the Gold Coast was a mere 12 tons, but by 1900 it had reached 536 tons, valued at £27,280. Exports steadily increased to 124,773 tons, valued at £10,056,298 in 1920, and by 1950 they reached 267,401 tons, valued at £34,604,291.

The Gold Coast is a country with an area of 91,843 square miles and a population of upwards of 4½ million. In the southern half of the territory there is a wet forest zone stretching from west to east, where the climate and rainfall provide suitable conditions for cocoa-growing.

As is to be expected in a country covering a wide extent of territory, there are considerable variations of climate. At Tafo the average rainfall is 63 inches per annum, and rain falls during 140 days. Shade temperatures range from about 90° F. to 65° F. for the greater part of the year. The mean relative humidity may be as high as 86 per cent in July and as low as 51 per cent in February. There is usually a long dry season from mid-November to mid-March and a short dry season in August. There are areas south and east of Tafo where the cocoa crop is adversely affected in some seasons by inadequate rainfall.

METHODS OF FARMING AND PLANTING

The African normally plants cocoa in his food-crop farm, and it is perhaps because it is reckoned the most valuable crop that the holding is referred to as a cocoa farm—the African himself calls it a farm.

His methods of planting cocoa are his own, evolved by himself, and so they differ in many respects from what is considered good plantation practice elsewhere. He planted in soils some of which were good, others less good or marginal, and some quite unsuited to cocoa. Having at first no knowledge of the soil requirements of cocoa, he adopted a method of trial and error until he arrived at a satisfactory response. In due course cocoa became an attractive crop, for it was easier to prepare for the market than palm oil and, when cocoa prices were good, it was much more profitable.

Farming practice in West Africa is commonly known as a system of "shifting cultivation," where a certain piece of land is cleared, farmed for two to three years, and then allowed to revert to forest.

It is normal to clear a fresh piece of land each year. This is done by cutting down the forest and burning the brushwood and trees, after which the land is planted in food crops, with cocoa interplanted. The operations of weeding and cultivation applied to the land under food-crops benefit the young cocoa, and enable it to become established before the food farm is abandoned. The cocoyams, plantains, and bananas and, possibly, cassava, provide the necessary ground cover and shade for the cocoa in the initial stages; the larger forest trees are left standing, either because it has proved too formidable a task to cut them down or because the farmer likes them as shade for his cocoa. When the food-farm is abandoned the young cocoa ceases to receive the customary weeding and cultivation, and so it takes another seven or eight years to come into bearing. Families and communities have grown cocoa extensively in their food-farms, and enterprising Africans have made large cocoa farms in the forest.

The West African farmer has always planted his cocoa at close spacing. It is not necessarily planted in lines or quite regularly, for the spacing varies from 3 feet to 4 feet. He has found close spacing useful, for even when a number of his cocoa trees have died there are still plenty left. The canopy of those that remain soon meets again to provide a cover for the ground and protect it from the sun. A close canopy has also the great value that the trees are less liable to attack by capsid bugs. When, after a lapse of years, the plantation has reached maturity, the canopy still spreads and closes up the space left when a tree has died. This type of planting often results in trees with long stems, which present difficulties at harvesting time and when measures for the control of disease are being carried out. The Department of Agriculture has strongly urged farmers to plant in straight lines, leaving sufficient space to allow operators with dusting or spraying machines to walk between them.

The simplicity of some of the methods of planting cocoa employed by the West African farmer has surprised experienced planters elsewhere. He plants seed by placing two or three at a stand, just below the surface, in cultivated soil. To plant a seedling, he opens the ground sufficiently to enable him to insert it. When planting a basketed seedling, he makes a hole just sufficiently large to accommodate the basket. When he wants an extra seedling, he merely extracts one from the site where two or three are growing together and replants it elsewhere.

Recent experiments and observations in the Gold Coast indicate that the less the soil is disturbed before planting out the seed or seedlings the better. The usual practices of deep cultivation, making

deep holes, exposing holes for weathering and filling them with surface soil preparatory to planting, appear to have no advantage and may even be regarded as a drawback.

It is usual to plant cocoa seed in September and October, as it is found to give better results than seed planted in June and July. Seedlings, on the other hand, are usually planted during the early rains, in May or early June.

The attention and care which the plantation receives after it has got under way depend on the amount of labour at the disposal of the farmer. If the farm is fairly near the village, then members of the family, or hired labour when available and cheap, will be engaged in keeping the plantation clean by weeding, thinning, and tidying-up, which includes removing black pods and dead branches. If, however, the farm is far away, and the family is small and labour is scarce, cultivation is likely to be neglected. On a mature farm, the work of "brushing"—that is mainly weeding and general tidying-up—may begin at any time from early July, and continue into August and September.

LABOUR REQUIRED

In his social and economic survey of Akokoaso (a Gold Coast village), W. H. Beckett estimated that the average time expended on various operations on the farm was twenty-five man-days per annum, divided roughly as follows: weeding 8, harvesting 15, carrying 1·5, other operations 0·5 man-days. Beckett rightly points out that the demand for labour is seasonal and that one-fifth of the man-days might be debited to October. The labour required for the production of one ton of cocoa may vary from 112 to 145 man-days, depending on the yield per acre and other factors.

SHADE

It is often said that cocoa in West Africa grows without shade. It is true that there are considerable areas, such as the northern part of Togoland, the land adjoining the Afram plains, and parts of Northern Ashanti, where cocoa grows with little or no shade; on the other hand, much of the cocoa is grown under varying degrees of shade provided by forest trees, and there is no doubt that in the greater part of the Gold Coast cocoa grows better where shade is provided. The farmers in the western part of Ashanti Province are becoming increasingly aware of the need for shade, and are taking the precaution of leaving sufficient trees where high forest is being exploited.

The forest plays an important part in protecting the cocoa from exposure to the cold north winds which blow periodically from November to February. When the forest belt in parts of the Eastern Province was removed in the course of food farming, cocoa trees were exposed to cold winds and many died.

HARVESTING, FERMENTING, DRYING

Harvesting of the main crop may begin in September, attain its maximum in November–December, and finish towards the end of January. A machete is used to detach the pods, which are taken to a central point where men cut them open, and women and children remove the beans by hand.

It is often erroneously stated that the West African farmer ferments his cocoa in holes in the ground. The method normally used is to lay banana or plantain leaves on a well-drained, dry piece of land, preferably on a slope. Here the fresh cocoa beans are heaped and more leaves are laid over them, so that the wrapping makes an almost air-tight container. The sides of the heap are sometimes supported by plantain or banana stems formed into a square. In spite of its simplicity, this arrangement can produce well-fermented cocoa, provided that the mass is turned at the proper intervals. The more progressive farmers use boxes or baskets as containers when fermenting the beans. Drying is done on raised platforms made of bush sticks and covered with mats of palm fronds.

DISEASES AND PESTS

Phytophthora and capsids made an early appearance in West Africa, but the incidence of capsids appears to have increased as they have adapted themselves more successfully to the introduced crop. They both now take a heavy toll of the crop annually. Frequent harvesting has been advocated as a means of limiting losses from *Phytophthora*, but as the farms are often remote and the farmer does not feel that the extra labour involved in this form of control would bring commensurate returns, it has not been put into practice. Capsids on young trees can be discouraged by the use of DDT emulsion, and this treatment is adopted in certain areas.

Although the large annual losses of crop from *Phytophthora* and capsids have always been recognized, they have in the past been accepted as something more or less inevitable. When swollen shoot —the killing disease due to virus—appeared, it gave rise to alarm. The first evidence of its presence was the dying-off of large areas of

cocoa, but some years elapsed before the cause of the disease was diagnosed. In 1940 the Gold Coast Department of Agriculture laid down an experiment in which diseased cocoa trees and the cocoa trees in immediate contact with them were cut out. This proved to be a successful form of control, and it was on the results of this experiment that the Department planned the large-scale campaign in 1945, which was begun in 1946 and has continued in operation ever since, with interruptions due to causes which were unconnected with the efficacy of this method of control, as such. The campaign saved the main producing areas of Ashanti Province and Togoland, with potential annual production of 125,000 tons and 30,000 tons respectively, and also other areas where the disease had not become too widespread to make this form of control ineffective.

PROS AND CONS OF PEASANT CULTURE

The conditions which have led to the present development in the Gold Coast are a favourable climate, suitable soils, a system of food-farming into which cocoa was introduced as a cash crop with little extra expense or labour, and an industrious and enterprising peasantry. The climate of the forest zone is on the whole suitable for cocoa, although large areas have been planted which are marginal as regards rainfall. Similarly, some of the cocoa is on good soils, some on near-marginal, and some on marginal soils. The peasant employs simple cultural methods which involve a minimum of capital expenditure and of recurrent costs. He is less seriously affected in times of low prices than are organized estates, as his outlay has been modest and he can usually find the means of growing enough food for himself when the returns from cocoa are insufficient.

The distribution of cocoa-planting in more or less isolated patches scattered over the whole forest belt has many disadvantages. Where plantations are isolated, far from roads, and the trees are not planted in regular rows, it is difficult to apply measures for the control of disease or provide other services to improve the industry. When, however, swollen shoot broke out, it did not spread as quickly as would probably have been the case had the plantations been contiguous.

The rapid and incautious exploitation of the forest as practised in West Africa, with the evils which follow in its train, is probably the greatest immediate danger to the industry. C. F. Charter estimates that of the 31,000 square miles which constitute the forest area of the Gold Coast, 18 per cent is in closed forest reserve; 17 per cent is in forest but not reserved; 9 per cent is under cocoa; and

56 per cent is under food-farms, bush fallow, and young or abandoned cocoa. He forecasts that at the present rate of forest exploitation the remaining unreserved high forest will have been removed for cocoa or food farming in about a decade. Charter foresees that, as the original accumulated fertility is dissipated in the course of farming annual crops and through lack of proper precautions to maintain fertility in the farms, there is a probability of a progressive decline in the output of cocoa from the Gold Coast. If his forecasts prove true, and there is much evidence to support them, cocoa will eventually be produced only on the richer soils which are capable of supporting it by virtue of their inherent fertility.

IMPROVING PEASANT CULTURE

From a long-term point of view the first essential is a system of planning which would show the best means of using the available land. This would define the areas which are respectively best suited for forest, for permanent crops, and for annual crop farming. Land-planning would be based on geological, ecological, and soil surveys, and on the distribution of the population and its needs. Land tenure and ownership, a difficult problem, would require careful consideration.

A long-term plan would envisage the reorganization of the present somewhat unsatisfactory pattern of land use. It would involve planting cocoa in contiguous plantations, and not in scattered fragmented holdings, as is so common at the present time. Such reorganization would make it economic to provide road services, services for the provision of pest and disease control, guidance in methods of maintaining soil fertility and in cultural practices, and centralized arrangements for fermenting and drying.

These radical changes could only be brought about through the recognition by the people concerned that they are necessary for the continuance of their prosperity and indeed for the very survival of their cocoa industry.

It has been advocated that a progressive approach should be made towards reorganizing peasant culture by establishing a number of peasant communities in areas where their land would be laid out on approved lines. Where Governments feel competent to undertake it, an "estate" might be laid out under Government supervision to demonstrate approved methods of culture. The estate would provide services for local peasant communities and the final development might be the integration of the estate with community land.

Estates independently owned and well conducted have had a good

influence on local plantation practice in the past, and when it is possible and practicable to have independently owned estates and peasant communities working in close harmony, mutually beneficial results can be achieved.

The methods by which fertility can best be maintained in established farms require careful study, but the restoration of fertility where it has declined beyond a certain point is much more difficult. The farmer has relied in the past on the regenerative effects of several years of bush or forest, and it is possible that if the proper number of forest trees were grown within the cocoa plantations this might arrest the decline, and help to restore fertility to the land. The extent to which mineral manures or cultivation of the farms would bring profitable returns on various soils in the Gold Coast has still to be investigated.

SOME PROBLEMS OF REPLANTING AND REHABILITATION

The problems of replanting and rehabilitation are aggravated by the fact that large tracts of cocoa have been killed by swollen shoot. In some places the land has been replanted immediately, in others it has reverted to forest, and in others again it has been farmed under annual crops. Where the soil has been exposed and soil fertility has been greatly reduced through leaching and erosion it is difficult to re-establish cocoa. The West African has been used to planting on land that has recently been under forest or bush for a number of years, and he has not until now encountered the difficulty of having to grow cocoa extensively on land where the forest litter is sparse or negligible. The means of restoring the environment needed by the cocoa tree, either by quick-growing forest or secondary trees, is one of the main problems of rehabilitation.

Re-establishment of cocoa is further complicated by the fact that the incidence of capsids is very high in some of the areas where much of the rehabilitation is required. The devastating effects of capsids on young trees may tend to discourage replanting, and make it impossible for even the more persevering planters to succeed.

THE PLACE OF COCOA IN A PEASANT ECONOMY

Whatever criticism may be levelled against some of the methods by which the African grows his cocoa, there is no doubt that it fits admirably into the economy of the country. Immediately north of the forest zone there is what is commonly referred to as the "Middle Belt." This is the chief food-producing area of the Gold Coast

and the main supplier of foodstuffs to the forest zone. As the cocoa plantations are spread right across the country from east to west, the returns derived from cocoa are distributed widely in this zone, and a great deal of the money finds its way to the farmers of the middle belt and other food-producing areas. It has sometimes been stated that it is unwise for the Gold Coast to grow so much cocoa in the forest belt to the exclusion of other crops. Cocoa is more suited to the forest area and much more profitable than any other crop that could be grown there. There are risks attached to growing one crop, such as the possibility of a disease which might destroy all the cocoa in a short period, just as coffee was destroyed in Ceylon. But there is no other cash crop which would give such good returns for the labour involved; it fits well into the African's way of life and is altogether an eminently suitable crop for him to grow. It is sound economic policy to grow cocoa on land particularly suited to it and to buy from elsewhere food for local needs. Although the forest belt is by no means fully occupied by cocoa, and a large quantity of local foodstuffs is raised here, there is no virtue in attempting to grow a diversity of cash crops where the soil and local conditions are pre-eminently suited to one particular crop.

THE FUTURE OF THE PEASANT INDUSTRY

The future of the peasant industry lies chiefly with the people themselves and the steps they take to preserve it. The eradication of virus-infected cocoa and the increasing control of virus are a prime necessity if the cocoa farms are to survive. Greatly increased control of capsids and *Phytophthora* would also pave the way for greater production, for it is conceded that, largely on account of these prevailing disabilities, the planting which has taken place of recent years will not give the return per acre that would normally be expected. The soils and the forest require all the skill that can be lavished on them in order that the heritage of fertility which has come down to the present generation may not be lost.

The West Africans have demonstrated their enterprise in building up a large and successful cocoa industry and in other ways. They have a great capacity for showing initiative and adaptability, and if science can find practical ways of meeting the troubles which beset cocoa at the present time, the African farmer will take full advantage of them.

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Chapter X

REHABILITATION OF COCOA PLANTATIONS IN TRINIDAD*

Historical—Defects of the Cultural System—The Aim of Rehabilitation—Sequence of Operations—Rehabilitation: Second Phase.

REHABILITATION is a simple modification of the traditional system of cocoa cultivation in Trinidad, designed to restore the yields of fields on good soils to their peak level by the systematic replacement of inferior trees.

HISTORICAL

Fields of seedling cocoa in Trinidad attained their peak yields some fifteen to twenty-five years after planting. Yields from poor soils subsequently sank to a level which precluded the possibility of profit, especially at the low prices of cocoa experienced during the 1930s, and most of these areas were either abandoned or converted to other crops. Yields from good cocoa soils also fell, but not to an unprofitable level except during the period of lowest cocoa prices.

The principal cultural operations on a cocoa estate were weeding, draining, pruning, and trimming the cocoa trees, and replacing missing ones. Only a few estates applied fertilizers. The weed growth in every field was cutlassed three or four times a year, or more or less often as required. Some planters made a systematic and thorough overhaul of the drains on a quarter of their cocoa acreage every year, while others preferred to clean only those drains requiring immediate attention, irrespective of their location. Similarly, some planters favoured a heavy pruning of each cocoa tree at intervals of about four years, whereas others preferred a light trimming at more frequent intervals. Nearly every planter supplied every blank or unoccupied cocoa site in every field every year, but practically none ever cut out and replaced a cocoa tree.

DEFECTS OF THE CULTURAL SYSTEM

There were two serious defects in this system of cultivation. First, by supplying seedlings in ones, twos, and threes all over the estate,

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it became impracticable to render the immediate environment of each supply suitable for its vigorous growth. Many seedlings died and had to be replaced, while others were retarded in growth. Special vigilance was required to prevent cutlassers from injuring the young supplies. Second, the failure to remove irreparably damaged trees resulted in the steady accumulation of low-yielding and unprofitable trees.

TABLE 1

PERCENTAGE OF TOTAL YIELD GIVEN BY PICKET QUARTILES ON "GOOD" AND "BAD" COCOA SOILS

Pickets	*Percentage of Total Yield*	
	"Good" Soil	*"Bad" Soil*
1st Quartile	1	0
2nd Quartile	13	1
3rd Quartile	28	15
4th Quartile	58	84

A cocoa tree on good soil may live for a hundred years or more, and may give a good yield throughout that period, but very few are spared to attain so great an age. The casualty rate among cocoa trees is surprisingly high. Less than half the trees in a field survive to the age of forty, and many of the casualties may have been renovated by suckers or replaced by supplies two or three times during that period. Original trees in a sixty-year-old field seldom muster more than 10 per cent of the total, and are rare in an eighty-year-old field. Thus, although the surviving trees tend to increase their yields with age, they diminish rapidly in number, and the ineffective method of replacing dead trees, coupled with the failure to cut out and supply poor-yielding trees, resulted in declining field yields. Hence, in mature fields on the best cocoa soils one-quarter of the cocoa sites (1st quartile) give practically no yield, and half of them (1st and 2nd quartiles) contribute only about one-seventh of the total field yield. But, at the other end of the scale, the highest yielding trees, although occupying only 25 per cent of the cocoa sites (4th quartile) produce about 60 per cent of the total yield (see Table 1).

On poor soils, half the pickets may yield next to nothing, and the 25 per cent comprising the highest yielders may be responsible for over 80 per cent of the field yield.

The records of seedling trees on good soils indicate that those supplies which survive to maturity give average yields similar to those previously given by the original trees at the same age. On poor soils supplies do not reach the yield given by the original trees at the same age. Moreover, the yields of the original trees on poor soils diminish after about twenty years, indicating a decline in soil fertility. For this reason rehabilitation cannot be carried out profitably on such poor soils.

THE AIM OF REHABILITATION

The aim of rehabilitation, then, is to raise the yields of the poorest 75 per cent of the pickets to that of the best 25 per cent. It is recommended that the initial programme of rehabilitation should be divided into two phases. The aim in the first phase should be to replace trees considered incapable of earning a profit, and that in the second phase to replace trees giving lower yields than can be expected from replacements.

The quantity of cocoa a tree must produce to pay its way will vary in relation to wage rates, the price of cocoa, etc., but was about 1 lb. when rehabilitation trials were commenced in the 1930s. To-day a little less than 1 lb. would suffice, but it is suggested that 1 lb. is a convenient dividing line between profitable and unprofitable trees.

TABLE 2

PERCENTAGE FREQUENCY OF TREE YIELD CLASSES ON "GOOD" AND "BAD" COCOA SOILS

Yield Class in lb. of cocoa	*"Good" Soils % Frequency*	*"Bad" Soils % Frequency*
0·0 to 1·0 ..	42	74
1·1 to 2·0 ..	21	13
2·1 to 3·0 ..	16	7
3·1 or more ..	21	6

The records of 40,000 cocoa pickets (or sites) on several good soil types in 1935 showed that 42 per cent of them produced not more than 1 lb. of cocoa. But some of these poor yielders consisted of young supplies which could be expected to yield appreciably more than 1 lb. of cocoa at more mature ages, and actual inspection within these fields indicated that 25 per cent to 35 per cent could be classified as unlikely to earn profits. These fields then yielded an average of

557 lb. of cocoa per acre, or nearly 2 lb. per tree, but now produce only 300 lb. per acre, and a recent inspection of some of these fields suggests that between 40 per cent and 60 per cent of the sites can be considered unprofitable. The Cocoa Board of Trinidad and Tobago offers assistance to planters who supply 35 per cent or more of the sites within any suitable field, and it is recommended that the planter should aim at supplying at least 40 per cent of the sites during the first phase of rehabilitation (see Table 2).

The records of 20,000 pickets on poor soil show that nearly three-quarters of the pickets yielded an average of not more than 1 lb. of cocoa. Moreover, there is a steady deterioration in field yield with increasing age, and only fields in their prime can be cultivated at a profit (see Table 3). Practically all such fields are long past their prime and most of them have been abandoned, but some planters still persist in burdening their good fields with the losses of the bad fields.

TABLE 3

PERCENTAGE FREQUENCY OF TREE YIELD CLASSES IN FIELDS OF DIFFERENT AGES ON A "BAD" COCOA SOIL

Yield Class in lb. of cocoa	*Ages of Fields in Years*				
	20	**25**	**30**	**40**	**45**
	% *Frequency*	% *Frequency*	% *Frequency*	% *Frequency*	% *Frequency*
0·0 to 1·0	59	67	72	80	91
1·1 to 2·0	18	17	14	11	6
2·1 to 3·0	11	8	7	5	2
3·1 or more	13	8	7	4	1
Yield per acre, lb.	346	251	226	162	85

SEQUENCE OF OPERATIONS

The first step in rehabilitation is to select those fields, or parts of fields, which are on recognized good cocoa soils. The planter should calculate how many acres he can rehabilitate each year and divide the good area into an appropriate number of blocks, say five, six, or

seven. Rehabilitation should be commenced on the best block where the response is likely to be quickest, unless a different order is dictated by some special consideration, such as the need to reform the entire drainage system of the estate. The more important operations are set forth in Table 4.

TABLE 4

REHABILITATION, FIRST PHASE. ORDER OF OPERATIONS

Year	*Months**	*Order*	*Operations*
1st	Oct.–Dec.	1	Blazing unprofitable trees.
2nd	March–May	2	Pruning seedling trees.
,,	May onwards	3	Planting shade and windbreaks.
,,	June onwards	4	Draining.
3rd	March onwards	5	Supplying shade and windbreaks.
,,	June–Sept.	6	Cutting out blazed trees.
,,	June–Sept.	7	Planting cocoa cuttings.
,,	June–Sept.	8	Applying fertilizer.
4th	April–May	9	Trimming cocoa seedlings.
,,	April–May	10	Applying fertilizer.
,,	June–Sept.	11	Supplying cocoa cuttings and seedlings.
5th	April–May	12	Shaping cocoa cuttings.
,,	April–May	13	Applying fertilizer.

First Year

Operation 1: Blazing Unprofitable Trees

The selection of trees for cutting-out should take place when the main crop has set, and before heavy pickings have been made. October, November, and December are usually suitable months for Trinidad but in abnormal seasons an earlier or later start should be made. The planter must set a particular standard of yield, say not more than ten pods of average value, to identify unprofitable trees. This standard may be adjusted upwards to eleven or twelve pods in years which promise good yields, and downwards to nine or eight pods in unfavourable seasons. Allowance should be made for the pod value of each doubtful tree. But prospective yield must not be the sole criterion. For example, a young, healthy, and well-shaped seedling bearing less than ten pods might be spared by reason of its immaturity. Similarly, trees occupying two, three, or four times the

* In normal years the dry season lasts from January to May, and the rest of the year is wet.

space originally allocated to them should not be retained unless they give correspondingly high yields. Trees which are highly susceptible to witches' broom should be cut out, even if they are high-bearers. The great majority of the trees selected for cutting-out during this first phase will consist of stunted or damaged trees which offer no prospect of developing the umbrella-shaped canopy of a well-balanced tree.

An experienced and active driver (foreman) or labourer should be trained to specialize in the process of rehabilitation. Two rows of cocoa trees should be examined at a time, the route being the same as that followed when pruning or picking cocoa. Each tree condemned to be cut out should be blazed as near as possible at waist height, and facing its opposite number in the other row, in order to facilitate identification when proceeding down the "ventun" (the space between two rows of cocoa trees). The blaze should be at least one foot long and deep enough to permit ready recognition some eighteen months to two years later when the tree will be cut. The planter will find that even in high-yielding, but unrehabilitated fields, at least 40 per cent of the pickets (including missing trees) will be available for planting, and in neglected or less favoured fields the percentage may be as high as sixty.

The cautious planter may find it interesting to check the selection of "dud" trees in March or April when he may find that a few late bearers have been blazed. A late-bearer is seldom a high-bearer for the latter usually carries pods of all sizes and flowers at most times of the year. It is highly improbable that a late-bearer will rank among the 25 per cent best bearers in the field, or give a yield comparable with that which can be expected from a clonal cutting, and as practically none would survive the second phase of rehabilitation, it is unnecessary to be conservative during the first phase.

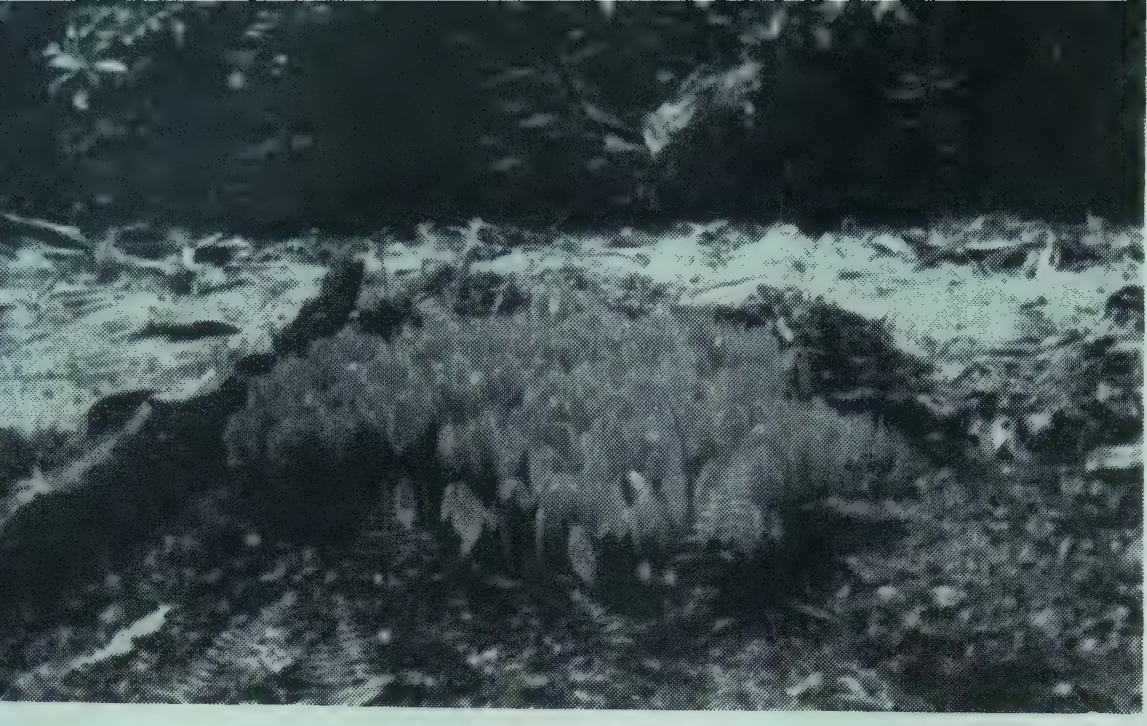
Second Year

Operation 2: Pruning Seedling Trees

The objects of heavy pruning are to remove weak, spindly, diseased and competitive branches, to improve the shape of the tree by encouraging vigorous and well-spaced new growth, to prevent interference with neighbouring seedling trees and to provide growing space for the cuttings which will be planted some thirteen to eighteen months later. Pruning should be started late in the dry season in order to afford the trees the full benefit of the approaching wet season. The Trinitario seedlings have a more spreading habit of growth than the Amelonado grown in West Africa, and the Trinidad

. Cocoa growing under
ade of mixed forest
ees in the Gold Coast

2. Exploitation of forest
and; maize being grown
after felling forest

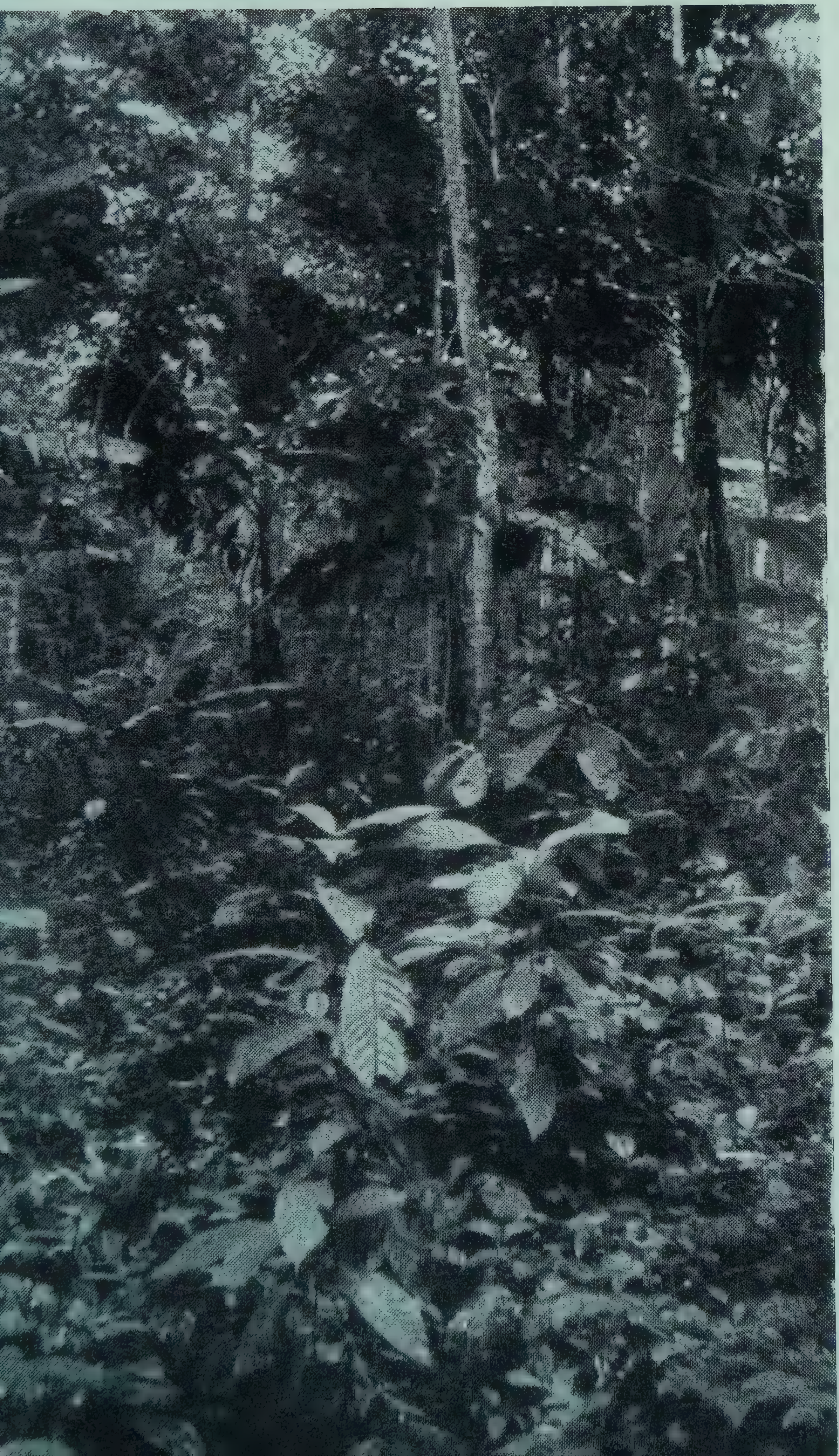


53. A farmer's nursery beside a small stream. The beans are covered with plantain leaves to protect them from rats

54. A farmer among his young cocoa trees, Western Province, Gold Coast. The shade consists of plantains, coco-yams and some forest trees

55. A farmer unrolling his drying mats in the morning

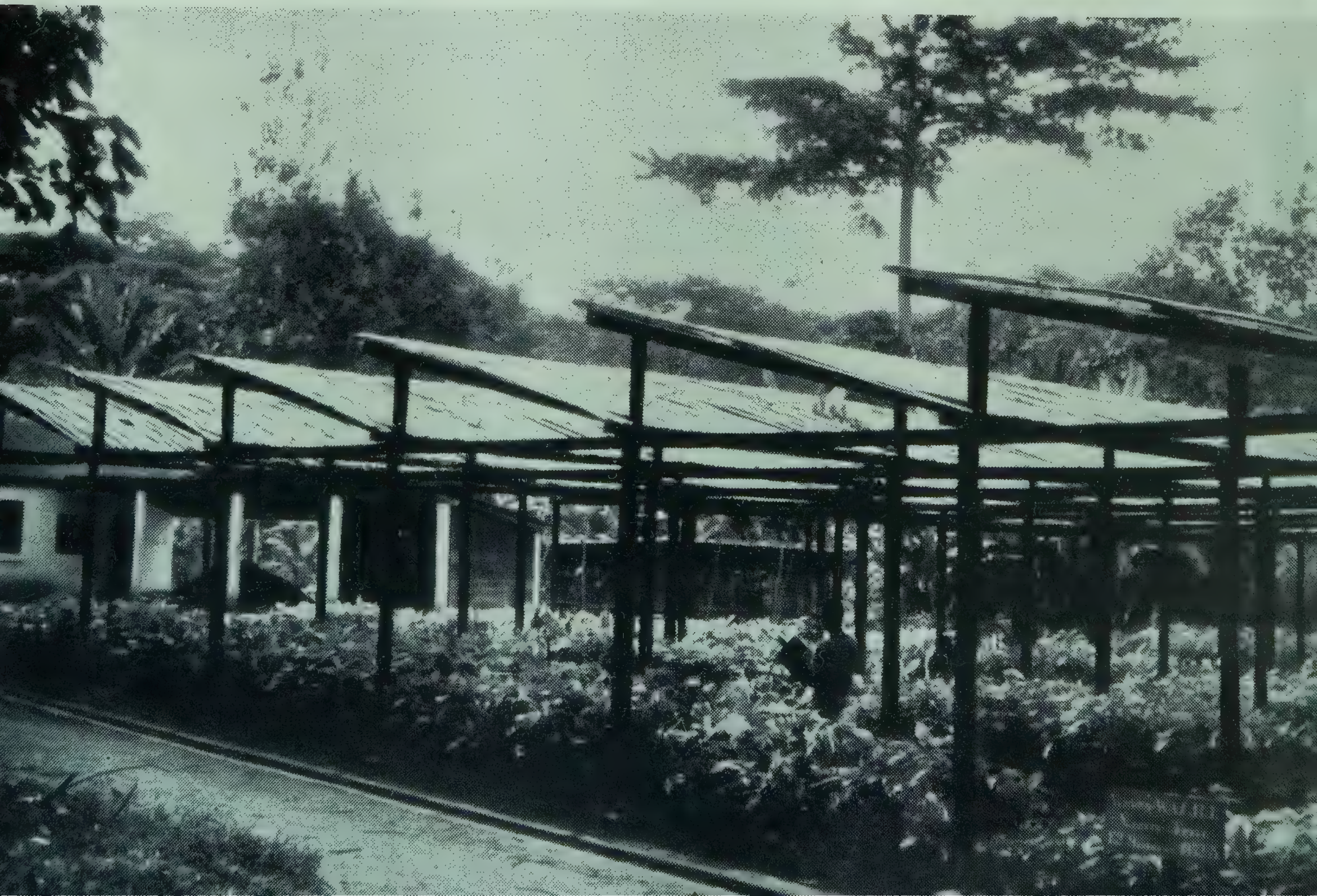
Young clonal trees
ted in gaps in a cocoa
l to replace missing trees
or poor bearers



57. Rehabilitation after swollen shoot. Young trees growing under mixed shade

58. Seedling nurseries in the Gold Coast. Shade of palm leaves supported by tree cassava stakes which later grow and provide shade themselves

59. Cocoa nurseries in the Gold Coast. Seedlings in baskets, shaded by a roof of split bamboo



planter aims at an umbrella-shaped canopy supported by three, four, or five vigorous and non-competitive branches. The seedling trees selected for cutting out are easily distinguished by their blazes, and, as the immediate effect of heavy pruning is to reduce yield, the planter should avoid the expense of pruning the condemned trees.

Operation 3: Planting Shade and Windbreaks

Formerly cocoa in Trinidad was almost invariably grown under the "permanent" shade of immortelles; the bocaré (*Erythrina glauca*) or water immortelle on the plains, and the anauca (*E. poeppigiana*) in the hills. The normal planting distance was 24 ft. by 24 ft., though an ultimate spacing of 48 ft. by 48 ft. was considered ideal. Both the bocaré and anauca are spiny, and once they grow out of reach from the ground they cannot be climbed for the purpose of pruning. The anauca may attain a height of 100 feet or more, and, when it falls, may mutilate many cocoa trees. Falling immortelles are responsible for more casualties among cocoa trees than any other single factor, and some planters have therefore adopted the Grenada practice of close replanting (e.g. 9 ft. by 9 ft. instead of 12 ft. by 12 ft.) of cocoa without permanent overhead shade. The results, however, have been disappointing, especially with I.C.S. 1, which constitute the bulk of the cuttings so far issued by the Cocoa Board, and most planters are now planting overhead shade.

Both varieties of immortelle are being heavily thinned by disease and substitutes must be found, but although many have been tried, none can yet be recommended with confidence. In the meantime, trials are being made with the bocaré in the hills where, at least for the present, it does not suffer from disease. A few specimens of bocaré are free from spines and it seems that these should be used for planting material so that they may be climbed and their growth controlled.

The question of the provision of overhead shade may be debatable but protection from wind is essential and windbreaks must be established on every site exposed to the easterly trade winds. Use is being made of pomerac, *Dracaena*, galba, and other evergreens which do not shed their leaves during the dry season when the winds are strongest.

Planting of *Gliricidia* and bocaré by cutting or stick should be started with the early showers and completed before the onset of the heavy rains. Further planting, though usually less successful, may be done during the short dry season. Planting of permanent shade and windbreaks by seed should await the rains.

The provision of temporary ground shade is vital to the rehabilitation process; planting should commence at least a year before

planting the cocoa cuttings. Cocoa planted in full sunlight makes poor growth unless given heavy and expensive dressings of fertilizer. A good ground cover keeps down weed growth, may provide revenue, furnishes débris, assists in preventing erosion, and protects the young cocoa plants from excessive sunlight. The objective should be a dappled shade with between 25 per cent and 50 per cent of full sunlight striking the ground. As a rough guide, it may be said that patches of sunlight exceeding one yard square indicate inadequate cover. The planter will appreciate that whereas excessive shade can be thinned quickly, additional shade takes months to establish, and it is therefore better to err on the side of excessive shade. Figs* (e.g. silk fig), bananas (Gros Michel and, recently, Lacatan), and tannias are long-established and current favourites in Trinidad. They can be planted at almost any time of the year, are hardy, vigorous, and easily controlled. Silk fig grows well in the open, but Gros Michel should be confined to sites protected by overhead shade. The bananas will occupy their sites for only about five years and may therefore escape the build-up of a heavy incidence of Panama disease and leaf spot. Figs and bananas, and to a lesser extent tannias, bring in revenue to offset part of the cost of rehabilitation. Many other ground covers, such as *Tephrosia*, *Canavalia*, kudzu, and pigeon pea, are being tried but most of them are expensive to establish and relatively slow in growth.

The convert to rehabilitation will be impatient to plant cocoa and may decide to plant ground shade and cocoa in the same year, but he will run the risk of a crippling percentage of casualties among the cocoa cuttings unless the following dry season is unusually favourable to them.

Third Year

Operation 4: Draining

The drainage system of the estate must be considered in its entirety and special attention must be given to main drains and outlets. On hilly estates, drains have usually been cut down the hill to ensure the rapid run-off of water, thereby causing gully erosion, whereas contour drains would lead the water off at non-erodible velocities to stabilized outlets. The principles of soil- and water-conservation are now well known, but their technical application is not well understood. The cutting and cleaning of drains by hand implements can be performed only during the wet season when the soil is workable and when the need for drains is made evident.

* In Trinidad, bananas other than Gros Michel and Lacatan are referred to as "figs".

Operation 5: Supplying Shade and Windbreaks

Steps should be taken to supply any casualties or deficiency in ground shade, overhead shade, and windbreaks.

Operation 6: Cutting-out Blazed Trees

The blazed trees can be cut out and the débris spread at any convenient time prior to planting the cuttings.

Operation 7: Planting Cocoa Cuttings

Cocoa planters in Trinidad and Tobago are able to obtain cuttings delivered to their estate by the Cocoa Board, free of cost and with a small cash subsidy. The Board concentrated until recently on the then most popular clone, I.C.S. 1, but the present policy is to supply a mixture of clones so that not less than half of the plants come from self-compatible clones and not more than one-quarter from any one clone. It is hoped that such a mixture will reduce the risks from pests and diseases and ensure a satisfactory blend of quality. Trials of the most promising clones have been laid down to ascertain their performance in different environments. The first choice of clones inevitably fell on early-bearers, but there are already indications that less precocious clones may prove superior in the long run. It is therefore probable that the clonal composition of cuttings distributed by the Cocoa Board will differ from district to district and from time to time.

Planting the cuttings should start with the onset of the rains and be pushed ahead as rapidly as the supply of cuttings and labour will permit, so that the plants may become well established before the following dry season. Plants issued by the Board during the earlier part of each planting season may be over a year old, but subsequent deliveries consist of progressively younger and smaller plants, with a diminishing period of wet season in which to establish themselves. The planter who has the foresight to plant ground shade in the previous year gets the pick of the cuttings. There is a risk of heavy mortality among cuttings planted after September.

Operation 8: Applying Fertilizer

Ideally, soil enriched with pen manure should be applied to each cocoa hole but no planter possesses a supply adequate for this purpose. The Cocoa Board provides fertilizer free of cost for application to cocoa cuttings.

The Board also offers fertilizers at half-cost for application to seedling trees in rehabilitated fields. Many previous trials of fertilizers have given disappointing results which may have been due, in

part, to the poor response of thriftless cocoa seedlings and the competition of shade trees. Now that the "dud" seedling trees have been removed, it is hoped that the relatively high-yielding survivors will give a profitable response.

The amount of fertilizer and the mixture to be applied will vary with different soils.

Fourth Year

Operation 9: Trimming Young Cocoa Plants

The young cocoa plants which were heavily pruned a year ago will have made vigorous new growth. Chupons and surplus fans should be removed so as to ensure the development of a well-shaped, balanced tree which does not interfere with its neighbours.

Operation 10: Applying Fertilizer

The application of fertilizers to cocoa cuttings and seedlings should be repeated annually. For the present, at least, it is recommended that fertilizers be applied towards the end of the dry season in order that they may be incorporated with the soil by the gentle showers that usually precede the heavy rains. This period is normally most convenient as regards labour, for reaping is tailing off and planting has not yet commenced.

Operation 11: Supplying Cocoa Cuttings and Seedlings

Casualties among cocoa cuttings are most numerous during their first season in the field, and especially among small ones planted late in the previous season. Choice plants of the most vigorous clones should be selected for supplying, and the operation should commence with the first favourable weather, because the plants have to contend with conditions which are no longer ideal. Supplying should not be confined to replacing dead rooted cuttings but should be extended to include those damaged and stunted cuttings which offer little promise of developing into vigorous trees. Supplying may also embrace with advantage the replacement of those seedlings which have died or been irreparably damaged during the year. Thereafter the planter should firmly reject the temptation to continue supplying replacements for odd casualties, since the growth of neighbouring cuttings and seedlings will have rendered conditions unfavourable, and it is far more economical to concentrate the resources of the estate on other fields needing rehabilitation. Open spaces caused by falling immortelles and other agencies should be planted immediately with ground shade and, where necessary, with overhead

shade, but the planting of cocoa cuttings should await the next phase of rehabilitation.

Fifth Year

Operation 12: Shaping Cocoa Cuttings

When the cuttings have been in the field for nearly two years they should be pruned, in order to secure the development of a well-shaped and balanced tree. Cuttings are produced exclusively from fan material and their habit of growth differs from that of the seedling with its main stem and jorquette of three, four, or five main branches. The cutting should be confined to three or four well-dispersed vigorous main stems, and weak and competing stems should be removed.

Operation 13: Applying Fertilizer

The application of fertilizer should be regarded as routine annual practice.

Arrondeering

Arrondeering or ring-weeding around the cocoa supplies is a routine operation of the utmost importance, and the removal of competitive weed growth must be repeated as often as necessary. Arrondeering is preferably done without the aid of any cutting implement, and should invariably precede the general cutlassing of weeds, in order to reduce the risk of injury to the cuttings.

These operations complete the first phase of the rehabilitation of a cocoa field. In the meantime the planter will have started the first phase of the same process in another section of the estate each year.

Rehabilitation temporarily reduces the crop in two ways. The loss from the "dud" trees cut out may range from 5 per cent to 10 per cent, but that from heavy pruning of the remaining seedling trees may be as much as 20 per cent to 30 per cent. The cocoa cuttings should bear a few pods during their third year in the field, and increase rapidly in yield in subsequent years. The beneficial effect of heavy pruning is first felt during the third season, when the yield of the seedlings should be higher than before pruning. The reduction in crop caused by rehabilitation is confined, of course, to the fields being rehabilitated, but the losses will increase as the second and third sections are treated. Thereafter the increasing yields of the rehabilitated fields should more than compensate for the loss of yield in the fields undergoing treatment, and the output of the estate should increase, slowly at first and then more rapidly until it has been at least doubled. Assuming that 40 per cent of the pickets are

supplied on one-fifth of the estate during each of five consecutive years, the maximum reduction in total output should be of the order of 15 per cent.

There is, however, some compensation. During the third, fourth, fifth, and sixth years the first section to be rehabilitated should earn a substantial revenue from figs and bananas, and a small income from tannias and, perhaps, cassava. This revenue will increase annually for several years as the ground shade on other rehabilitated sections reaches maturity.

REHABILITATION: SECOND PHASE

Immediately after the first phase of rehabilitation has been started on the last section of the estate the planter should return to the first section to commence the second phase of rehabilitation in which the aim is to replace trees giving lower yields than can be expected from replacements.

The records of cocoa cuttings grown under shade have been spectacular, both in early and high bearing, but they were obtained from selected sites on exceptionally fertile soils and enjoyed constant care and attention. Experience with cuttings is too limited to permit an accurate prediction of yields, and it is desirable to proceed with caution, in the knowledge that errors can be corrected in subsequent phases of rehabilitation. It seems safe to assume, however, that the yields of cuttings will average at least 3 lb. of cocoa per annum and it is therefore recommended that the planter should replace mature seedling trees giving less than 2½ lb. of cocoa. The second phase of rehabilitation has not yet been reached on any estate known to the writer and the technique of identifying poor-bearers has not yet been established. A trial, made by a labourer skilled in the first phase of rehabilitation, in a field he had not previously seen but for which there exist records of individual tree yields over many years, suggests that a single inspection may suffice.

The operations comprising the second phase of rehabilitation are identical with those of the first. The temporary loss of crops from the trees cut out will be much more serious than during the first phase, but the increments in yield from the established cuttings should more than outweigh the loss. At the end of the second phase there will remain only about 25 per cent of the original seedling trees, but each will be a highly profitable bearer. Rehabilitation should at least treble the yield of an estate.

Rehabilitation should not end with the second phase but should become routine practice, otherwise casualties will accumulate and

eventually production will fall. It is recommended that a fraction of the estate, say one-fifth, should be treated each year, but the number of trees cut out and supplied should be substantially less than in the first and second phases.

The traditional system of supplying every blank site every year is now universally condemned and rehabilitation is gaining rapidly in popularity, but re-planting and inter-planting are still favoured by some planters. The complete replanting of an estate, whether quickly or slowly accomplished, entails a loss equivalent to about three years' cocoa crop. It necessitates the destruction of certain seedling trees which, though few in number, contribute a large percentage of the crop and revenue, and some of which may outyield the cuttings planted to replace them. To those planters who command the financial resources, supply of labour, and number of cuttings required, re-planting offers a quicker but more expensive means of achieving the same end as rehabilitation. Few planters are so happily situated, and there is no doubt that rehabilitation makes more effective use of the inadequate number of expensive cuttings at present available.

The inter-planting of the standing seedling trees with cocoa cuttings, and the systematic cutting back and eventual removal of the seedlings, enable the planter to retain a large portion of the revenue from cocoa while the cuttings are coming into bearing. It requires an unusual degree of courage and ruthlessness to cut back heavy-bearing seedlings in the interest of non-bearing-cuttings, and the cuttings are generally retarded in growth by the too dense shade of the seedlings. Inter-planting, like re-planting, necessitates an extravagant number of costly cocoa cuttings and the sacrifice of high-yielding seedlings.

In any case, re-planting and inter-planting do not remove, but merely postpone, the need for rehabilitation, and it is claimed that rehabilitation offers a sure and relatively inexpensive means of restoring the yields of cocoa estates on good cocoa soils.

REFERENCES

Further details of yields, and of the effect of age and soil type on yield, are given in:

Shephard, C. Y. *The cacao industry of Trinidad: Some economic aspects, III. The examination of the effects of soil type and age on yield.* (I.C.T.A., Trinidad, 1937.)

Chapter XI

PESTS AND DISEASES

Methods of Control—PESTS: Capsids—Capsids in West Africa—Capsids in Other Countries—Thrips—Insects which attack Leaves and Shoots—Insects which attack the Main Stem—Insects which attack Pods—Termites—Birds and Mammals—DISEASES: Black Pod—Witches' Broom—Resistant Trees—Monilia—Mealy Pod—Anthracnose—Botryodiplodia theobromae—Black Spot and Bark Rot—Pink Disease—Thread Blights—Red Rust (Algal disease)—Root Diseases—Epiphytes and Parasitic Plants.

Cocoa is attacked by many insect pests—the most important being capsids—and suffers from diseases such as black pod, witches' broom, and swollen shoot. Serious losses in production are caused by capsids, which are found in most cocoa-growing countries, and by black pod disease, which occurs universally. The virus diseases are dealt with in a separate chapter (page 145); they cause great devastation in West Africa and occur also in Trinidad. Witches' broom is at present confined to South America and the West Indies.

Losses are also caused by rats, squirrels, and birds, and in some countries parasitic plants are troublesome.

METHODS OF CONTROL

Cultural methods, which include strict attention to the processes of draining, pruning, adjusting shade, weeding, and mulching of the plantation, make the trees less susceptible to certain pests and diseases. Where trees are kept in a healthy condition they recover more readily from attacks.

Direct methods of control include the cutting out of diseased trees, pruning affected parts, and collecting insects by hand.

Insecticides are also employed and are applied as sprays and dusts. They are usually classified as follows:

(1) *Stomach poisons.* These are mostly arsenicals, of which lead arsenate is a typical example. The spray is made by mixing ½ to 1 oz. of the chemical in a gallon of water.

(2) *Contact insecticides.* Nicotine sulphate, used as a spray against aphides and thrips, is made up by dissolving 4 oz. of soap in 4 gallons of water and adding 1 oz. of 40 per cent nicotine sulphate. Pyrethrum is also used as a spray or dust. DDT and gammexane are effective against capsids and have a prolonged residual action. They are usually applied as sprays or dusts, but DDT in the form of an emulsion is sometimes applied with a brush.

(3) *Systemic insecticides.* These are a comparatively recent discovery. They are absorbed by the plants and will poison some of the insects which suck sap from them.

(4) *Fumigants.* In this group there are many chemicals which are used against pests of stored products. Cocoa which is badly infested with moths is usually fumigated with methyl bromide. Fumigants are also applied to the soil; carbon bisulphide is used in this way against ants' nests.

The fungicide most commonly used in the tropics is Bordeaux mixture. It has been in use for nearly seventy years, and is still one of the most effective, provided that it is correctly prepared.

Hopes for the future seem mainly to lie in the breeding of varieties of cocoa which are resistant or immune to pests and diseases. This is of necessity a long-term project as it takes years to evolve and distribute such varieties. Even then there is no guarantee that these will not behave differently in a new environment.

Selections resistant to witches' broom disease have been found in South America. Trees unaffected by black pod have been found in several countries and selection for resistance to thrips has been made in Trinidad.

Pests are sometimes controlled by biological means. Where pests are present in great numbers, a parasite or predator is introduced for the purpose of reducing them to a level at which the damage is insignificant. For instance, coffee in Kenya is attacked by a mealybug *Pseudococcus kenyae*, which occurs in large numbers. A parasite was introduced which for a time reduced them to small proportions. The problem of mealybugs which transmit virus diseases of cocoa is different, as the number involved is comparatively small, and all of them must be killed to prevent the spread of the virus they carry.

PESTS OF COCOA

CAPSIDS

The capsid family of insects ranks foremost in West Africa among the pests of cocoa. Capsids are also major pests in Java, Ceylon, and New Guinea, but in South America they are less important.

CAPSIDS IN WEST AFRICA

The two species which cause most of the damage are *Sahlbergella singularis*, or brown capsid, which is about half an inch long and speckled brown in colour, and *Distantiella theobroma*, or black capsid, which is the same size but considerably darker in colour. Both these species are indigenous to West Africa and have been found on *Ceiba pentandra*, the silk cotton tree, and on certain other trees. Both species were first reported on cocoa at about the same time in 1908–9. *S. singularis* is now found throughout the greater part of the cocoa-growing area of West Africa from Sierra Leone to the Belgian Congo, and it appears to have found cocoa so much to its liking that it has transferred itself almost entirely to this introduced crop. *D. theobroma* is to be found from Sierra Leone to the French Cameroons.

The life-histories of these two capsids are similar. The eggs are laid on twigs, pods, or pod-stalks, and are inserted inside the tissues. The wingless nymphs hatch out after 12 to 18 days, and the nymphal stage lasts for an average of 25 days, after which time the winged adult appears. The adult female begins laying eggs about a week later and continues to do so for the rest of her life, which may last for as long as six weeks.

Both nymphs and adults feed on cocoa, confining themselves to pods and young shoots and preferring pods to chupons and chupons to fans. Both species attack young plants and old trees, although *D. theobroma* prefers young seedlings and *S. singularis* is commoner on mature trees.

When feeding, the capsid thrusts its mouth-parts into the tissues of the plant. It then injects its poisonous saliva, which probably assists in the extraction of the plant's sap. Each feeding-puncture, of which a capsid will make twenty-four to thirty-six in a day, becomes a dark brown or black spot, which frequently becomes infected with a fungus, *Calonectria rigidiuscula*.

The numbers of capsids per acre is never very great, as even in a badly affected area there may be less than a thousand capsids to an acre, but two or three capsids on a young plant can cause its death.

S. singularis is parasitized by a wasp-like insect, *Euphorus sahlbergella*. The degree of parasitism may rise as high as 30 per cent at certain times of the year, but this does not prevent the numbers of *S. singularis* from increasing. The parasite might effect better control if it were not itself parasitized. No parasite of *D. theobroma* has so far been found.

During the crop season when there are a large number of pods on the trees, the capsids will feed on them and the pods become speckled

with black spots. Pods, however, are rarely so seriously damaged that they have to be discarded.

The number of capsids increases during the harvesting period, after which they move to the canopy of the cocoa trees and feed on young shoots; this may result in widespread damage known as capsid "blast."

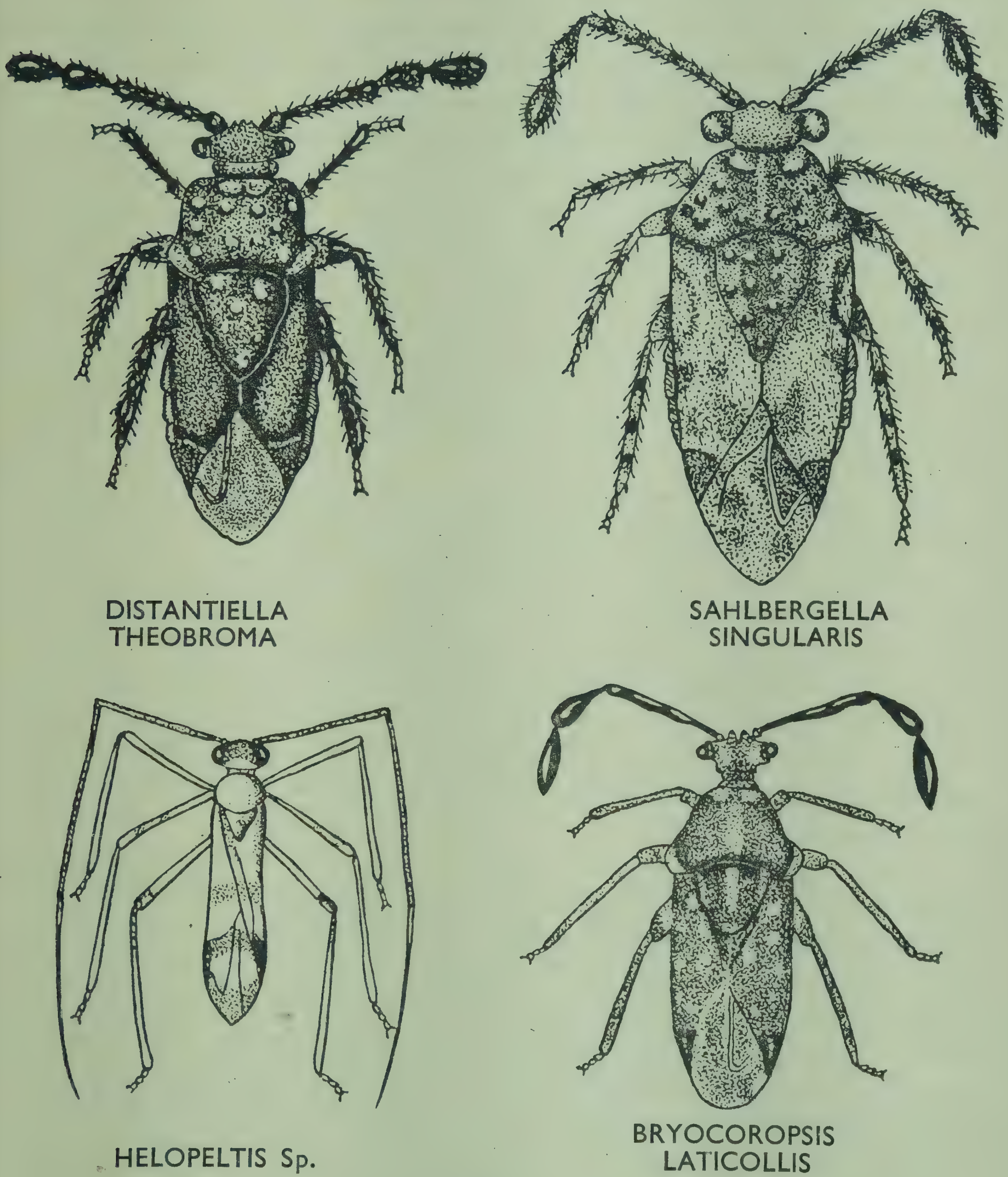


FIG. 5

FOUR SPECIES OF CAPSIDS WHICH ATTACK COCOA IN WEST AFRICA

The bottom left figure is magnified 3 times, the others are magnified 4 times.

Capsid "pockets" occur where the fall of a forest tree has damaged cocoa trees. These respond by producing young shoots which are attractive to capsids and are heavily attacked by them. The die-back so caused is followed by the growth of more young shoots which are in turn attacked. This will continue until the trees weaken and die out, but all the time more trees are being exposed to capsid attack, thereby enlarging the pocket.

If untreated, capsid pockets rarely recover, and it was found at W.A.C.R.I. that much of the permanent damage in capsid pockets is due to the fungus *Calonectria rigidiuscula.*

This fungus normally attacks dead rather than live wood. It can be established in a wound on a healthy cocoa tree, and may remain dormant there. If, however, the tree is weakened in some way, as for instance by drought, capsid attack, or canker, it cannot resist the spread of the fungus which will bring about the death of branches and sometimes of the whole tree.

Capsid attack on young cocoa occurs when it is two or three feet high. If the capsid lesions are numerous, the leaves and shoots are rapidly killed. Further flushes may be similarly destroyed until the plants are killed.

The pest can, therefore, prevent the establishment of cocoa or delay its reaching the bearing stage by several years.

Young trees can be protected from severe attacks by painting them with 2·5 per cent DDT emulsion, a method of control which has been developed at W.A.C.R.I. The most suitable form of emulsion is 20 to 25 per cent DDT dissolved in oil, used with an emulsifier, such as "teepol." One part of the DDT solution is mixed with nine parts of water. They will mix better if the water is added to the oil rather than the oil to the water, the mixture being thoroughly stirred.

As the capsids hide in crevices and forks of the trees during the day, there is no need to cover the whole tree with insecticide, and the method of control is to apply the DDT emulsion to the forks and stems of the younger branches with a brush. This is a comparatively simple task when the trees are small, but becomes slower and more laborious, and eventually impracticable, as the trees grow bigger. DDT emulsion has a considerable residual effect which may last for as long as four or five months, and the number of applications can, therefore, be limited to three or four per annum.

A successful method of control has been developed at the Lukolela estates in the Belgian Congo by which the trees are dusted with gammexane. The gammexane preparation employed is called Nioka and contains 6 per cent gamma isomer. The trees on this estate do

not normally grow as tall as the close-planted trees in West Africa, and the gammexane powder can be applied by means of a small hand-operated dusting machine. The routine procedure is to employ twenty-five men to work through a section of the plantation, cutting off dead branches and doing general sanitation. Three other men are employed, each with a "Mistral" dusting machine, who attend to any capsid damage which is reported. An area of 125 acres can be treated in a day.

It should be possible to design a machine to apply gammexane dust to the taller cocoa trees of other countries.

Comparatively recently, a third capsid species, *Bryocoropsis laticollis*, has been found on cocoa. In the Gold Coast it was first recorded in 1939. In Nigeria the same species has been seen on plants other than cocoa; it appears to be moving from its original host to cocoa and may become a major pest. At present it is relatively harmless, the damage being almost entirely confined to the pods.

Helopeltis species is about the same size as the other capsids, but has a slender yellowish body and long thin antennae and legs.

Members of this genus are found on a variety of plants throughout West and Central Africa. On cocoa, *Helopeltis* species feeds almost exclusively on the pods and a heavy attack on young pods may prevent their maturing. The feeding-punctures on older pods cause little direct damage, but may lead to subsequent attack by fungi.

Capsids in Other Countries

Various *Helopeltis* species cause much damage in Java and Ceylon. They attack pods, shoots, and leaf-stalks. Young pods may be badly damaged if heavily attacked, and young shoots may be killed.

The numbers of the insect vary considerably with the season, being very numerous in the wet season and almost negligible in the dry.

At one time three different control methods were used; namely, catching the insects by hand, destroying them by applying a flame to the pods, and by introducing a black ant (*Doliderchus bituberculatus*) into the cocoa field. This ant, although it did not attack the capsids, made the trees unattractive to them. Nowadays, the capsids are controlled by the use of DDT and gammexane dusts.

In New Guinea cocoa was first planted at least fifty years ago but capsid damage was not experienced until 1949. The species found in the territory of New Guinea belong to the genera *Parabryocoropsis* and *Pseudodoniella*. They primarily attack pods and, as these insects are considerably more plentiful than they are in West Africa, the amount of mechanical damage is considerable. This is greatly

increased by the entry of other insects into the capsid lesions, and, what is of greater importance, by the entry of a fungus, *Gleosporium* species. This causes most damage during the wet season when the main crop is on the trees.

Control methods are at present in the experimental stage, though application of DDT or gammexane as a dust appears promising.

In some districts of Ecuador a capsid, which is known locally as "mosquilla," causes serious damage to pods. Two species, *Monalonion atratum* and *M. dissimulation*, are found.

Another species of the same genus (*M. xanthophilum*) attacks cocoa in Brazil, where the local name for it is "chupança do cacáu."

Cocoa Thrips

This small insect (*Selenothrips rubrocinctus*) is a serious pest of cocoa in the West Indies, São Tomé, and certain South American countries. It also occurs in West Africa and has been reported from New Guinea, but it rarely causes serious damage in either of these countries.

Fig. 6
SELENOTHRIPS RUBROCINCTUS
Greatly magnified

The cocoa thrips is small, only 1–1½ mm. long. The adults are black, but the nymphs are yellow with a red band across the base of the abdomen.

Thrips live on a wide range of host plants, being very common on cashew trees. On cocoa trees they live on the underside of the leaves where their eggs are laid and where large colonies of nymphs are to be found. They pierce the leaf-cells and suck the sap; this damages the outer layer of the leaf, which becomes silvered. R. G. Fennah writes: "The nymphs carry the abdomen curved upward, with a drop of clear fluid poised on the hairs at its apex. This is periodically released and drops on the leaf surface where it dries to form a brownish spot. The speckling caused by the presence of many such dots on the partially dried or silvered tissue is characteristic of thrips injury."

The damaged leaves will die if the attack is severe, and trees may be defoliated. A severely attacked tree will respond by flushing and the young flushes may in turn be attacked. Repeated attacks may kill a tree.

In Surinam, attacks by thrips were followed by damage by a fungus (*Diplodia*), which the weakened trees were unable to resist.

Pods are also attacked. They are not damaged, but become discoloured, turning a dirty brown colour, which makes it difficult to determine when the pods are ripe.

Unhealthy trees suffer most from thrips attack. It was found in Trinidad that severe attacks were associated with rapid falls in soil moisture content, coupled with high atmospheric humidity; the severity of the damage was enhanced by the low potash status of the soil. Over-exposure to wind or sun has been thought to be an important cause of thrips attack, and some fields of the clone I.C.S. 1 which were planted without shade have suffered severely from thrips.

It might be expected that thrips would be prevalent in West Africa, but they are not common. This may be due to the fact that the numbers of the insect are kept in check by the hymenopterous parasite, *Dasyscapus parvipennis.* At times the proportion of parasitized thrips has reached 80 per cent. This insect was introduced into Trinidad in the hope that it would control thrips there but it has not become established.

Severe outbreaks of thrips can be controlled by spraying with nicotine. Bordeaux mixture and slaked lime, when sprayed on to the leaves, act as repellents but do not kill the insects.

In many outbreaks certain trees escape damage and appear to be resistant to thrips. Search for resistant trees was undertaken in Trinidad and a tree known as RT 18, which is also a good commercial type, was selected. This selection was included in a clonal trial at River Estate, but it did not yield well under the conditions there.

INSECTS WHICH ATTACK LEAVES AND SHOOTS

ANTS

One of the worst pests of cocoa in Brazil is the "enxerto" ant (*Azteca paraensis* var. *bondari*), which has become a serious menace during the past twenty-five years.

It makes its nest in the epiphytes of the cocoa trees, the pods and shoots of which it gnaws to provide further nest-material. This in itself causes some damage to the trees, but the ants also protect mealybugs (*Pseudococcus citri*) and other scale insects, which suck sap from the trees and weaken them.

The epiphytes, too, cause harm by interfering with the flowering of the trees. Individually, the epiphytes, ants, and mealybugs would do little damage to the cocoa trees, but in association with one another they create a serious problem.

Another species of ant (*Azteca chartifex*), almost equally important, also protects aphides, scales, and mealybugs, and makes nests

out of material from pods and shoots. Two others, *Crematogaster* sp. and *Solenopsis* sp., the fire ant, cause similar damage and attend similar insects. The last-named has a very painful sting which causes difficulties in harvesting. It is reported that these ants can be controlled by spraying with gammexane.

In other parts of South America and the West Indies damage by ants is localized and sporadic, the "parasol" ants (*Atta cephalotes*) being the chief enemy. They make very large nests to which they carry large quantities of leaves and small branches. They can be destroyed by pouring carbon bisulphide or a 2 per cent solution of chlordane down the holes of the nests; carbon bisulphide acts as a fumigant, but is highly inflammable.

Mealybugs, Aphides, and Scale Insects

Apart from their importance as vectors of virus diseases of cocoa, mealybugs are occasionally found in large enough numbers to become a primary pest. Aphides and scale insects have also been reported as troublesome. These insects suck the sap from the tree, and may cause a considerable drain on it when they occur in large numbers.

In the Gold Coast the aphid *Toxoptera coffeae* is sometimes troublesome. This small insect is dark brown to black in colour and attacks young shoots and leaves. The leaves become curled and later they may harden and fall off. The aphides are attended by small black ants, *Pheidole* sp. Control measures are rarely necessary.

In Fiji aphides (*Aphis gossypii*) are normally found on young shoots and leaves. Mealybugs (*Pseudococcus citri*) attack young pods also and may cause withering of the pod, malformation, or delayed ripening.

Leaf-eating Beetles

Beetles belonging to the families Chrysomelidae and Scarabeidae cause serious damage to young plants in some countries.

The genus *Adoretus* occurs in West Africa, Java, Ceylon, Fiji, and Samoa. These beetles feed on young flushes during the night, making numerous holes in the leaves, thereby checking growth.

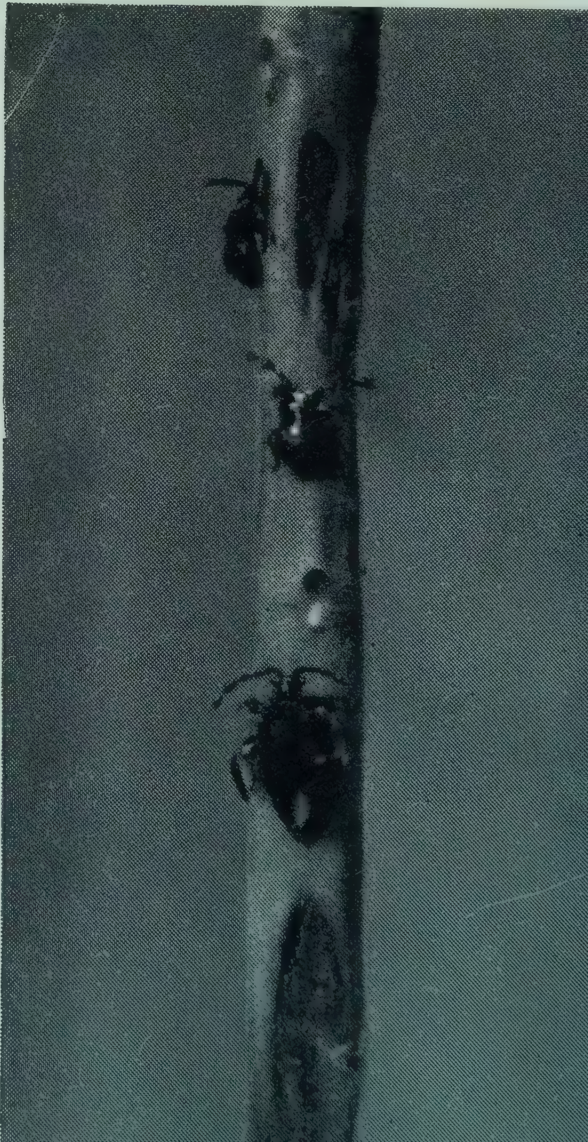
In Samoa young plants are protected by a ring of stones built around them up to a height of one foot or more, but beetle attack occurs as soon as the plants emerge above the stones.

In some countries leaf-eating beetles appear suddenly and cause serious damage. Spraying the young plants with DDT emulsion or lead arsenate will control them, but it must be done as soon as the first damage is detected.

60. Young cocoa trees heavily damaged by capsids

61. A young cocoa tree which has been severely damaged by capsids

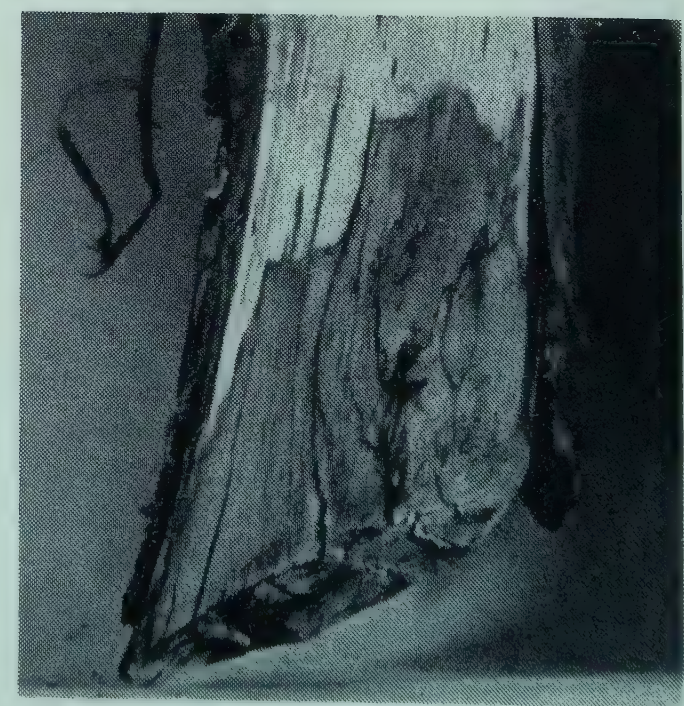
62. Capsids on young green stem. The lower insect is an adult, the other two are nymphs. There are two capsid lesions on the stem



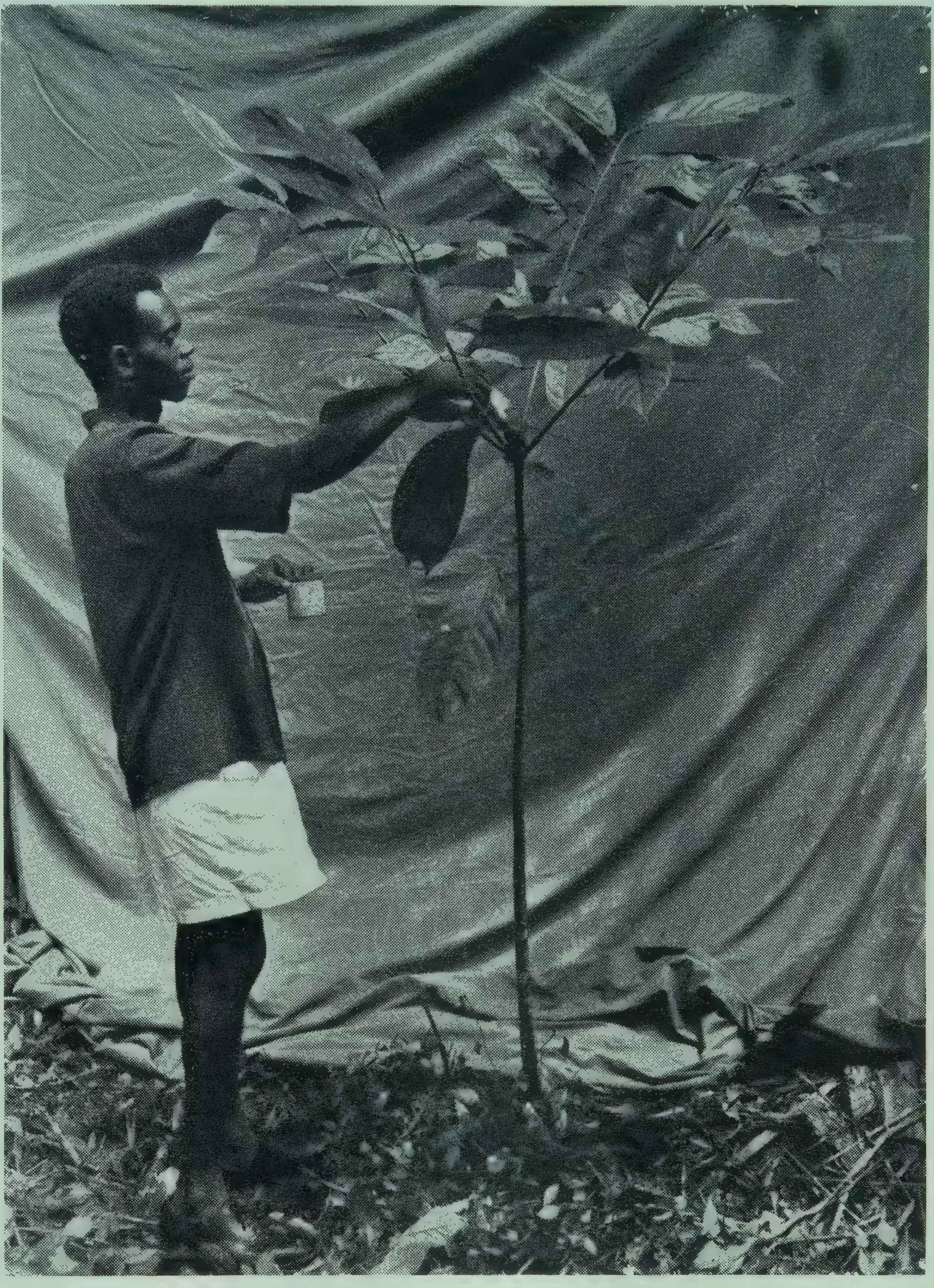
63. Capsid attack on cocoa pods. Damage due to *Sahlbergella* and *Distantiella*

64. Capsid attack on cocoa pods. Damage due to *Helopeltis*

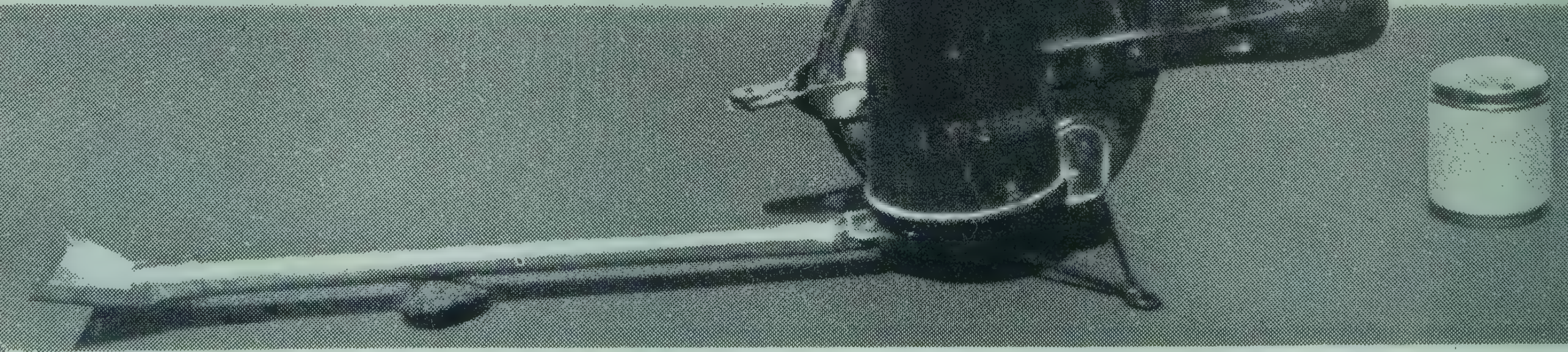
65. Stems damaged by capsids. (*Left to right*): (*a*) old cankered stem; (*b*) healed capsid lesions; (*c*) "hammer knock" condition due to feeding by capsids; (*d*) healthy stem



66. A branch from a cocoa tree which has been attacked by capsids and subsequently invaded by a fungus, as indicated by the dark discolouration



67. Control of capsids, Gold Coast. A young tree being painted with DDT emulsion



68. Control of capsids, Belgian Congo. A hand-operated machine—*Le Mistral*—which is used for dusting cocoa

MOTHS

Several moths attack the leaves and shoots of cocoa trees.

In New Guinea a moth, *Pansepta teleturga*, has recently been found attacking cocoa. The larvae feed under a webbing of frass and consume large areas of bark; this may lead to the death of the branches and even of whole trees when colonies of larvae are at work. No method of control has been evolved.

In Fiji and the New Hebrides the caterpillars of the moth *Adoxophyes fasciculana* attack the leaves, and in the Gold Coast a small green Tineid moth, *Earias biplaga*, attacks leaf buds and young leaves.

INSECTS WHICH ATTACK THE MAIN STEM

LONGICORN BEETLES

These fairly large beetles belong to the family Cerambycidae, members of which are to be found in most cocoa-growing countries, where they are pests of varying importance. Where they cause considerable damage control measures can be taken. The life histories of these species of beetles, and the damage caused by them, are similar, so one of them is dealt with in detail and the distinctive features of others will be described.

COCOA BEETLE

This fairly large Longicorn beetle (*Steirastoma breve*) causes considerable damage to cocoa plantations in Trinidad, Grenada, and some South American countries.

The adult beetles are black, nearly one inch in length, and have two long antennae.

The adult female makes holes in the bark in which she lays her eggs, and then seals the holes. After hatching, the larvae feed under the bark, making tunnels in the wood. They feed for two or three months before pupating, and in that time the tunnels may go right round a branch, thereby ring-barking it. As the eggs are often laid near the fork of a tree and sometimes on the main stem, serious damage may result.

FIG 7.
STEIRASTOMA BREVE
Slightly magnified

Young trees, especially those between three and five years old, suffer most from beetle damage, though trees vary considerably in the extent to which they are attacked. Beetle damage was surveyed

at River Estate, where it was found that certain clones suffered much less damage than others.

The adult beetles gnaw the bark of the young branches. Normally this causes purely superficial damage and it is unusual for it to be deep enough to be serious. The control measure most commonly employed is to collect the adult beetles by hand. They are fairly easily caught and large numbers may be destroyed, but it is doubtful whether the method provides effective control.

The beetle has a number of other host plants, some of them related to cocoa. This fact was made use of twenty or thirty years ago when it was the practice to lay traps—branches of other host plants—in which the beetle was expected to lay its eggs. These were usually placed close to the cocoa trees and were collected at intervals and burnt. This practice died out during the years of depression and has not been revived.

Parasites and predators exist but they appear to have little effect on the beetle population.

Spraying with lead arsenate is probably the best method of control. This can be confined to those parts of the young trees, such as the main stem and large branches, that are most likely to be affected.

Other Longicorn Beetles

In Java the beetle *Glenea novemguttata* is a serious pest. It is about half an inch in length and causes the same type of damage as has been described above.

Another member of the same genus, *G. aluensis*, has been reported from New Guinea. It became troublesome after the last war owing to the neglect of plantations, but it appears to be a less serious pest now that the plantations have returned to a normal degree of cleanliness.

Various members of the genus *Monohammus* occur in New Guinea and Samoa, where they are minor pests. In New Hebrides *M. holotephrus* attacks the trunks and large branches of the tree and therefore causes more serious damage.

Various Longicorn beetles have been found on cocoa in West Africa. Members of the genera *Tragocephala*, *Mallodon*, and *Glenea* occur in the Gold Coast, but all are minor pests.

Weevil Borer

This insect (*Pantorhytes plutus*) ranks as a major pest of cocoa in New Guinea and is also found in Samoa. During its larval and adult life, which extends over two years, it bores into the wood and

causes extensive damage. The adults also cause considerable damage by chewing the soft bark of young shoots.

INSECTS WHICH ATTACK PODS

Cocoa Moth

This moth (*Acrocercops cramerella*) is a major pest in Java. The eggs are usually laid in the furrows of the pods and, after hatching out, the larvae burrow through the pod wall and live in the pod, making tunnels in the pulp. Although they do not attack the beans, both the yield and the quality of the cocoa are reduced.

Only one method of control has been successful. Complete removal of all pods, ripe and unripe, once a year, thereby breaking the life-cycle, has provided a certain degree of control, but the moth has alternative hosts, such as the cola tree (*Cola acuminata*) and the numbers of the moth build up again after a few months.

This moth also occurs in Dutch New Guinea. In both countries it has been observed that smooth-podded Amelonado trees are less susceptible to attack.

Cocoa Pod Borer

This small Noctuid moth (*Characoma stictograpta*) is found in the Gold Coast, where it is a minor pest. It flies at night and lays its eggs at the stalk end of the pod. The larvae tunnel in the pod and produce a brown sticky mass of frass between the pod and the trunk. The damage is not serious but the wound provides an entry for fungi.

TERMITES

Termites have been reported as a minor pest in West Africa, Ceylon, Java, Samoa, New Guinea, New Hebrides, and Grenada.

Termites normally attack dead wood. They enter cocoa trees through wounds and will follow up damage caused by other insects or fungi. Considerable damage by termites has been reported from the New Hebrides where it prevents the healing of wounds, which consequently become enlarged. The trees may even be killed.

Attack by termites can be minimized by the removal of dead wood, by avoiding damage by machetes, by the killing of the queen in the termite nests by fumigants, and by maintaining control of other pests and diseases; in other words, by good estate sanitation.

BIRDS AND MAMMALS

Rats and squirrels occur in most cocoa-growing countries and cause losses by opening the pods, extracting the beans, and sucking

the pulp off them. They rarely eat the beans, but scatter them about, hence the expression in West Africa of sowing cocoa "squirrel fashion."

In São Tomé, Java, and Ecuador these animals are reckoned to cause serious damage and have to be controlled by shooting or poisoning. The rat poison "Warfarin" has been used. It is mixed with meal or corn (not paddi), using one part of "Warfarin" to nineteen parts of meal. To be effective, several meals of poisoned bait have to be consumed; and the rats do not readily become shy of the bait.

The mongoose was imported into Trinidad to control rats. This it did very successfully, but it became a pest itself, killing fowls and beneficial birds and animals.

In Sierra Leone and Nigeria monkeys cause considerable losses of pods.

In New Guinea and the New Hebrides losses due to parrots may be as high as 25 per cent.

In the West Indies woodpeckers make holes in the pods and eat the pulp. The pods are subsequently invaded by various fungi.

DISEASES OF COCOA

Black Pod Disease

The fungus *Phytophthora palmivora* causes black pod disease (known as brown pod in Brazil), and occurs in every cocoa-growing country to a greater or lesser degree. The annual loss caused by this disease in all cocoa-growing countries amounts to a very large tonnage. The incidence of the disease varies with the rainfall and rainfall distribution, and with humidity and temperature, being on the whole higher in the wetter cocoa-growing countries. It is particularly troublesome in the Cameroons at high altitudes, as these are subject to prolonged mists during the cropping season.

This fungus attacks several tropical crops, including rubber, coconuts, cotton, and citrus as well as cocoa. Generally speaking, each crop is attacked by a different strain of the fungus, but more than one strain can attack cocoa.

Pod rot is by far the most important damage caused by *Phytophthora palmivora* but in some countries the fungus also causes a canker and a chupon wilt.

Black pod has been investigated by several scientists. Dade did much work on this disease in the Gold Coast during the late 'twenties, and in more recent times it has been studied at Turrialba in Costa Rica, by Thorold in Nigeria, and by Owen in the Gold Coast.

The fungus attacks pods of all ages. In Costa Rica it has been found that the fungus causes a considerable loss of young cherelles, which appears to be associated with damage caused by a membracid insect. The fungus will destroy the beans in young pods, but when fully-ripe pods are lightly attacked, some of the beans may be saved by frequent harvesting.

The first symptom of black pod infection is a brown spot which appears about five days after infection. This spot rapidly enlarges and darkens until the whole pod is invaded and blackened. Two days after the appearance of the first symptoms, a white web of mycelium and conidia is formed on the surface of the pod, the conidia or spores being the main source of infection. The pod continues to produce spores for about ten days, after which time it will have been invaded by several other fungi which will suppress *Phytophthora*.

The spores produced on the surface of the pod are spread by raindrops, insects, and possibly by air currents. Rain falling on an infected pod will carry spores to healthy pods lower down the trunk, and neighbouring pods may be infected by splashes. Many types of insects carry spores, spreading the disease from pod to pod and from tree to tree.

The spores germinate when the relative humidity is high. In Costa Rica it has been claimed that free moisture is essential for germination, but in Nigeria it was found that germination takes place when the relative humidity is 95 per cent or more. In Brazil the incidence of fungus increases rapidly when the temperature drops as low as 15° C.

Dade showed that the spread of the disease depends mainly on the relative humidity of the atmosphere. In the cocoa areas of the Gold Coast the relative humidity is high at night, being around 95 to 100 per cent, but during the day there is considerable variation. When the relative humidity remains high both day and night, the disease spreads most rapidly. Although the fungus can infect healthy pods, injured pods are attacked more easily and invaded more readily. A longer period of high humidity may be necessary for infection of healthy pods.

Pod infections are often associated with some predisposing factor. Dade analysed the infections on a number of trial plots and found that 25 per cent of the infections were due to contact with a diseased pod; a similar percentage followed injury to the pod, and a variable percentage—5 to 27 per cent—were due to drip; the remainder had no predisposing factor. Most of the injuries were caused by insects, although some were due to knife cuts. Insect injuries were much

more numerous in the drier situations, so that infection due to injury was more important where humidity was lower.

Diseased pods on the trees are undoubtedly the main source of infection of other pods, but there is some doubt as to the amount of infection caused by diseased pods or old husks on the ground.

After the fungus has completely invaded the pod, it will pass up the pod-stalk and may infect the flower cushion. This may lead to the formation of a local canker in the cushion, which may infect the pods in the next crop, the fungus moving down the peduncle into the growing pod.

The removal of diseased pods at frequent intervals has been shown to reduce the incidence of the disease considerably. Since the fungus will begin to produce spores within two days of the appearance of the first symptom, the trees must be inspected every other day and infected pods removed, but such precautions call for a good deal of labour.

In countries where the incidence of the disease is high, experiments have shown that spraying not only reduces the losses from black pod to a low level but is also an economic proposition. In Costa Rica, where losses of 50 per cent or more are the rule, the harvest of healthy pods has been doubled by monthly spraying with 1 per cent Bordeaux mixture. This was applied at the rate of 150 gallons per acre by means of a permanent installation of pipes which delivered the fungicide from a central tank.

In Fernando Po it is the regular practice to spray with a 2 per cent Bordeaux mixture two to four times a season according to the rainfall.

In Nigeria and the Cameroons, spraying with Bordeaux mixture has been followed by remarkable increases in yield.

In Western Samoa a high-yielding tree called Lafi No. 7 has not carried a single black pod for several seasons, although it has been surrounded by diseased trees. Other similar trees have been reported from Brazil and the Cameroons. Should any one of these trees prove to be immune to black pod, it will be of great value, although as already pointed out it would take many years before production over large areas could be affected.

The canker caused by *P. palmivora* varies in incidence. In many important cocoa-growing countries it is insignificant, but in Trinidad and Ceylon canker has caused considerable damage and sometimes has proved fatal to the trees. Damage is also reported from the New Hebrides. A canker appears as a moist spot on the bark of the stem or a main branch, and it becomes enlarged to form a dark area which exudes a reddish liquid. The extent of the canker can be seen by removing the bark, whereupon the dark affected part is seen.

The effect of a canker varies greatly from tree to tree. It may develop and spread to such an extent that the tree is killed; on the other hand, the tree may recover, sealing off the canker with a layer of cork cambium. In those countries where there is a dry season of several months, the trees make their best progress towards recovery during the dry months.

Criollo trees are more susceptible to canker than Forastero, hybrids being intermediate in this respect and variable in their susceptibility. As the proportion of Criollo and hybrid trees has decreased, the importance of this disease has declined considerably. Cankers rarely, if ever, form spores, so they must originate from infected pods, possibly by way of the pod stalk and flower cushion.

The chupon wilt caused by *P. palmivora* is relatively unimportant, occurring only in Central America where it does little damage.

Witches' Broom Disease

This disease is caused by the fungus *Marasmius perniciosus* which is specific to cocoa and some other *Theobroma* species. It is indigenous to South America, probably originating in the Upper Amazon valley from which it has spread to the surrounding cocoa-growing countries—Ecuador, Colombia, Venezuela, Peru, and the Guianas. The disease was first studied and the fungus described in Surinam. It did great damage in that country and contributed to the decline of cocoa there.

In 1928 the disease was found in Trinidad and it has since spread further, being found in Tobago in 1939 and in Grenada in 1948. It does not occur in Central America nor in the main cocoa-growing area of Bahia in Brazil, nor is it found outside the New World.

The most obvious symptoms of the disease are the brooms or hypertrophied shoots which are much thicker than healthy shoots and bear many short lateral shoots with undeveloped leaves. Infected flower cushions often form cushion brooms, producing vegetative shoots as well as flowers. Infected flowers have thickened stalks, and occasionally abnormal strawberry-shaped pods are formed but these do not develop to maturity.

The effect of the infection on the growing pod will vary with its age at the time of infection. Cherelles become carrot-shaped and turn black and hard before reaching maturity. Small pods become distorted, the infected side swelling and later turning hard. In both these cases the beans are destroyed. Pods which are even further developed at the time of infection show a hard, blackened area around the point of infection. All the beans in the pod may be

damaged, and it is only where pods are nearly ripe when attacked that the beans can be saved.

The disease is spread by spores produced on small mushrooms which develop on dead brooms and infected pods. The spores are released at night, when the atmosphere is nearly saturated with moisture, and are dispersed by air currents. The spores are short-lived, dying within forty-eight hours unless they alight in a place suitable for their development.

Only young developing tissues are attacked. On a vegetative bud the broom appears about six weeks after infection, depending on the flushing of the tree, and after a further six to eight weeks the broom dries up and dies. Mushrooms will not be formed on a dead broom for at least three months, and generally not until five to six months after it has died.

Individually, the small pink mushrooms do not live long, only about three days after reaching maturity, but a large broom may produce as many as thirty mushrooms in a week. Any broom may continue to produce mushrooms for eighteen months, although there is considerable seasonal variation in the numbers of mushrooms formed. The greatest numbers are found in the wet season, and mushroom growth ceases in the dry season.

If the disease is uncontrolled, the trees will become covered with hundreds of brooms, and pod losses may rise as high as 70 per cent. Damage is worst in river valleys where conditions are humid but is considerably less on the slopes of the hills. Ridges between valleys may act as natural barriers to the spread of the disease.

Losses can be reduced by the periodical removal of brooms. Brooms are removed along with about six inches of the healthy stem, and diseased cushions are cut out flush with the bark. This should be done at regular intervals of four months; more frequent treatment is unnecessary owing to the time taken for mushrooms to develop. In Trinidad, removal twice a year, in April or May and again in October, is thought to be sufficient. Infected material is destroyed by burning or burying.

Spraying trials have been made, using various fungicides. Although a degree of control has been obtained, the treatment has been uneconomic at normal yields. When a spraying programme can be worked out to control witches' broom and other pod diseases at the same time, this will, of course, reduce the overall costs.

Resistant Trees

Some years ago Dr. Pound made two expeditions to the head-waters of the Amazon, to look for immune or resistant varieties.

Many specimens were brought back to Trinidad and tested for resistance. Two of these, SCA 6 and 12, are apparently immune. These clones were propagated and planted fairly widely, but it was found that they produced small beans which might be unacceptable commercially. These clones are now being used in the breeding programme in Trinidad.

Another clone from South America, IMC 67, which appears to be highly resistant to the fungus, is under investigation.

Monilia Disease

This disease (*Monilia* sp.) was first observed in Ecuador in 1914. It is now of major importance in that country, causing an average loss of 40 per cent of pods, and it has also spread to Colombia, Brazil, and western Venezuela, being prevalent in wet districts.

The disease affects young pods, but when they reach a certain size they become immune. The first definite symptoms of the disease are seen on pods three to four inches long, which show a slight protuberance and, when cut open, reveal greyish strands. On more mature pods the fungus produces various effects. There may be little external sign of infection except that a few dark spots may be produced or the pod may be covered with a whitish growth. On the Venezuelan or Trinitario type of cocoa, the fungus forms a grey patch surrounded by a white margin. A diseased pod is heavier than a healthy one of the same size, and is more difficult to open. The interior of the pod is enveloped in watery matter and the beans are worthless.

In Ecuador the Cacao Nacional variety appears to be more resistant to the disease than later introductions.

The recommended control measures are spraying with Bordeaux mixture, together with cultural measures to reduce humidity in the plantation.

Mealy Pod

This fungus (*Trachysphaeria fructigena*) only occurs in West Africa, where it attacks coffee as well as cocoa. Pod losses vary from district to district, but are generally less than 1 per cent, although in some districts they may exceed 10 per cent in very wet years.

The first symptom of the disease is a brown area at the point of infection, which rapidly spreads and darkens. Then the surface becomes encrusted with a mealy mass of spores, which is white at first but turns pinkish later. If young pods are attacked they become dry and light, and the beans will be rendered useless, but if the pods are attacked at a more mature stage the beans can be saved.

The spores are disseminated by wind and water and will readily attack a damaged pod, but it has not been proved that the fungus can attack healthy pods.

As the spread of the disease is favoured by humid conditions, the control measures include thinning and pruning of the cocoa trees, removal of epiphytes, and weeding and draining which will reduce humidity in the cocoa field. In addition, all infected pods should be removed from the trees.

Anthracnose

This disease (*Colletotrichum* sp.) is found in many cocoa-growing countries but it is of little economic importance.

The fungus attacks pods of all ages, forming a brown spot which turns darker and becomes sunken. Pustules of yellow spores are formed in the spots. Young pods may be destroyed, but the beans will not be affected in older pods.

Diplodia Pod Rot

Botryodiplodia theobromae (or *Diplodia theobromae*) is a weak parasite and occurs in all cocoa-growing countries. It causes a pod rot which is called diplodia pod rot or brown pod. (This should not be confused with black pod, a quite distinct disease due to *Phytophthora palmivora*.)

The first symptom of diplodia pod rot is a brown spot which turns black and becomes enlarged until the whole pod is invaded. When a pod infected by *B. theobromae* has reached this stage, large numbers of black spores having the appearance of soot are produced on the surface of the pod, and the beans are destroyed.

In the Gold Coast a condition known as "warty pod" is thought to be caused by a strain of this fungus. Attack by *B. theobromae* can only occur through wounds, which may be caused by insects, squirrels, or birds, such as woodpeckers. Healthy pods are not attacked. Losses from the disease will be reduced by the control of pests which wound pods, and by removal of infected material.

The fungus also causes a die-back which has been reported from South and Central America, the West Indies, Africa, and Asia. A chupon wilt, due to this fungus, occurs in New Guinea.

Die-back occurs on trees which have been weakened by thrips attack, lack of shade or windbreak, poor drainage, drought, or some other cause. Attacks may also occur on trees which have been pruned carelessly. The disease begins at the end of the branches, which dry out and die, the leaves turn yellow and fall off, and the wood discolours and turns grey.

Sphaeronema Black Spot and Bark Rot

This disease (*Sphaeronema* sp.) is found in Ecuador. It only attacks pods which are almost ripe, producing a dark spot with a white patch of mycelium in the centre of the spot. Diseased pods are lighter than healthy ones but the beans can usually be saved. The damage to pods is normally light, but the fungus also causes a bark rot which has killed large numbers of trees.

The fungus can attack young healthy shoots, but it enters older parts of the tree only through wounds. The bark around a wound becomes discoloured and exudes a dark liquid. Attacks of this disease can be reduced by the careful use of sharp-edged implements in the plantation.

Pink Disease

This disease (*Corticium salmonicolor*) occurs in South America, the West Indies, the Cameroons, and New Guinea, attacking a wide range of hosts.

The fungus attacks cocoa trees growing under very wet conditions. In New Guinea it is associated with the use of pigeon peas (*Cajanus cajan*) as lateral shade for cocoa. Twigs and small branches become covered with a thin white mycelium which later turns pink and on which the spores are formed. The branches are defoliated and killed, but it is rare for the damage to extend beyond the loss of a few branches.

Attacks are dealt with by removing the affected branches. Incidence of attack may be reduced by improving the drainage in the plantation and adjusting the canopy of the cocoa and shade trees to admit more light.

Thread Blights

Several species of fungi cause thread blight, a disease which affects many host plants in the tropics. In West Africa two species, *Marasmius scandens* and *M. byssicola*, are found. In the West Indies, Brazil, New Guinea, and New Hebrides, *Corticium* species cause thread blights.

In attacks by these fungi, the creamy-white mycelium can be clearly seen as it runs along the twigs and sends out branches to the leaves over the back of which it ramifies in numerous fine threads. The leaves are killed, turn a dark brown colour, and remain suspended from the twigs by a thread of mycelium. The damage does not normally extend beyond the killing of leaves and small branches, though according to reports from the French Cameroons, the trees are sometimes killed.

The incidence of the disease is worst in damp places in the wet season and it normally spreads by contact. It is controlled by removing the infected parts. Where it occurs frequently, the humidity should be reduced by decreasing the shade or pruning the trees.

Horse-hair blights, the mycelium of which resembles horse-hair, are found on cocoa in several countries, but do no damage.

Red Rust or Algal Disease

Three species of algae belonging to the genus *Cephaleuros* cause this disease, which is of minor importance on cocoa. It occurs in the Gold Coast, São Tomé, Belgian Congo, West Indies, and Brazil.

The symptoms are small, round patches, orange-yellow to rust-red in colour, which are found on the upper surface of the leaves. The injury to the leaves is slight, but young branches also become infected and dark spots are formed on the bark. Only weak, unhealthy trees suffer from this disease so it will not cause any damage where conditions for growth are good. Red rust has been found on young cocoa trees three to four years old, when the temporary shade has been removed and the permanent shade trees are not big enough to shade the young cocoa trees adequately. Sudden changes in the degree of shade weaken the trees and may lead to damage or loss from various pests and diseases.

ROOT DISEASES

Root diseases attack cocoa in most cocoa-growing countries and are generally localized. They cause losses of a few trees from time to time and are encountered most frequently in partly-thinned forest or where the forest has recently been removed. The usual symptoms of an attack by a root disease are sudden yellowing and wilting of the leaves, which turn brown and remain on the tree after it has died.

Root diseases are usually spread by root contact, although some of the fungi can also grow through the soil for some distance. It is generally considered, though it is not finally proved, that there is very little spread of root diseases by means of spores.

The most common method adopted for the control of root diseases is to cut down the affected tree and remove and burn both the tree and the stump. An isolation trench, to prevent the spread of the fungus outwards, is dug at least eighteen inches deep round the site of the tree which has been removed. It may be advisable to dig trenches around adjacent trees also, and to extend them in order to

provide better drainage in the vicinity of the area of the outbreak.

The more important root diseases are:

Collar Crack

The fungus *Armillaria mellea* attacks many trees in temperate and tropical regions and is commonly known as "Honey Agaric." It causes a serious root disease called "collar crack," which is found in parts of Togoland, the Cameroons, and in São Tomé.

The fungus will attack cocoa trees of all ages and other hosts as well. It infects the tree through the lateral roots and then spreads upwards and downwards attacking the stem and tap-root. On the stem the mycelium of the fungus develops inwards along the medullary rays, then it thickens and exerts great pressure on the trunk of the tree, causing it to crack. The cracks normally extend for three to five feet, but may reach ten feet above the ground. An attack by this fungus is nearly always fatal to the tree. The fungus produces clusters of mushrooms at ground level, which at first are white but turn yellow and finally blacken.

The fungus can spread through the soil from one host to another and it flourishes in damp conditions.

Root Diseases due to *Rosellinia* Species

Three species of the genus *Rosellinia* have been found to attack cocoa, but only one is of any importance. *R. pepo*, or "black root disease," has caused considerable damage to cocoa in the West Indies and has also been reported from Colombia and New Guinea. It attacks many other crops and can be recognized by the smoky-grey mycelium which covers the roots and the white mycelial fans which can be found beneath the bark of the roots.

The disease occurs in patches which spread slowly, although the symptoms may appear suddenly on individual trees. Infected trees should be cut out and the ground should be exposed to the sun.

Root Diseases due to *Fomes* Species

Fomes lignosus, the "white root disease," is sometimes found on cocoa in the Gold Coast and Ceylon. Attacks usually occur after planting on newly cleared land and are worst in damp low-lying areas. The fungus causes the leaves to wither and fall, and this is followed by a general die-back. The soft, white mycelium can be found on the roots, and a black ring can be seen if the trunk is sawn across.

Collar Rot

The fungus *Ustulina deusta* has been found in the Gold Coast, but it is more important as a cocoa parasite in the South Pacific, being

reported from New Guinea and the New Hebrides. In the latter country it occurs in patches, especially in damp places. The fungus produces large brown brackets above ground level, but there is no external mycelium to be found on the roots. As the fungus spreads by root contact, affected trees should be isolated by digging a ditch two to three feet deep around them, and they should be uprooted.

EPIPHYTES AND PARASITIC PLANTS

Epiphytes are plants which use other plants for support but do not draw any food from them. They are common on cocoa trees in some countries. They interfere with the flowering of the tree and should be removed.

Mistletoes, on the other hand, are semi-parasitic plants, drawing some of their food from the host plant. They are common on cocoa trees in West Africa and Ceylon, and also occur in the West Indies, where they are known as bird vines, because they have sticky seeds which are disseminated by birds. Mistletoes can be removed by pruning. These plants belong to the family Loranthaceae and their roots penetrate the tissues of the host from which they obtain water and salts; in time this will cause a die-back of the branch above the point at which the mistletoe is attached. If the infestation is heavy, the yield will be reduced.

VIRUS DISEASES

Virus diseases of cocoa are of sufficient importance for them to be dealt with in a separate chapter.

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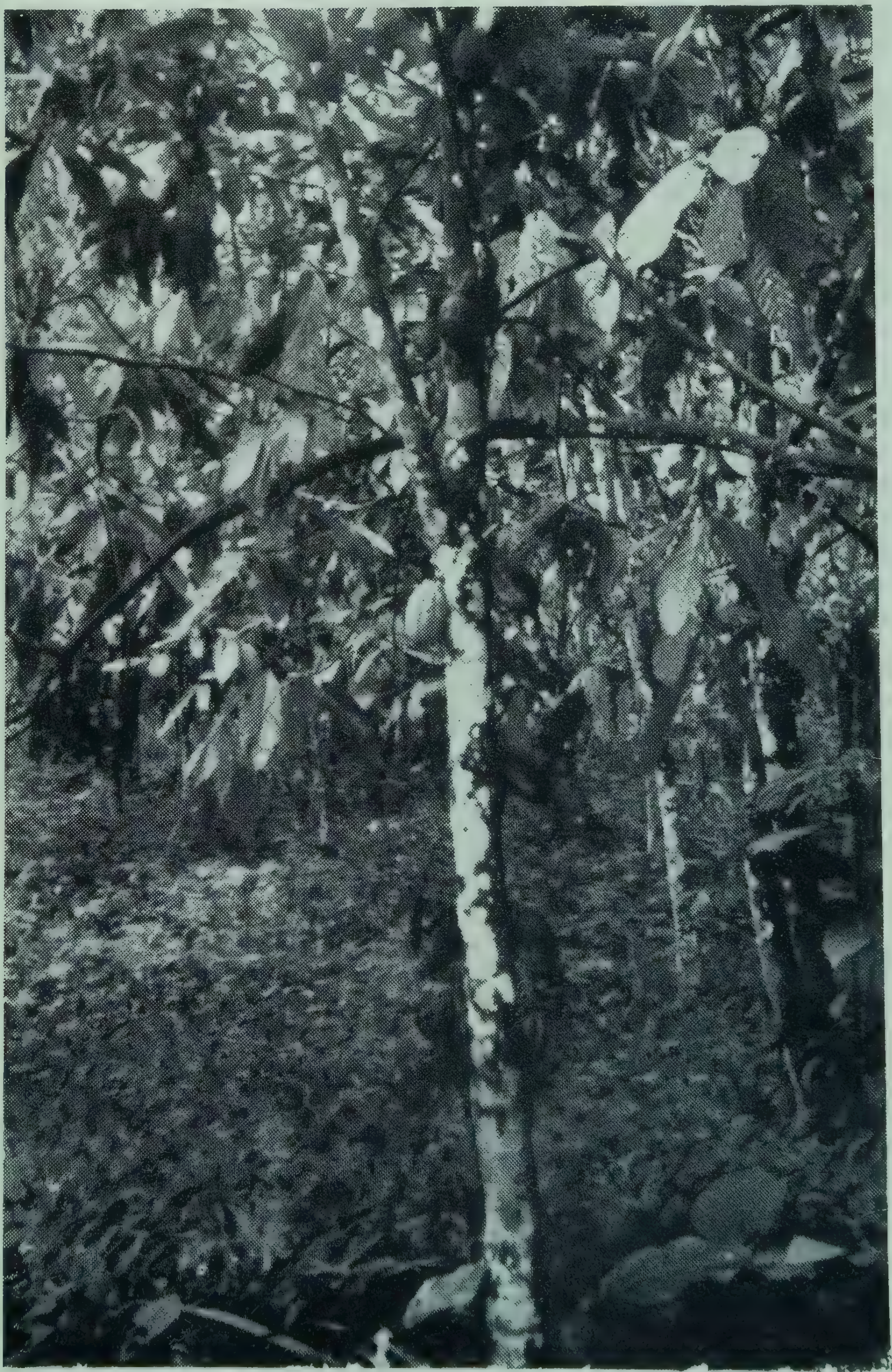
69. Cocoa pods affected by black pod. The pod on the left has been affected in two places. The right-hand pod has been completely invaded by fungus



70. A cocoa tree bearing several black pods

75. Cocoa trees dying of swollen shoot virus

Chapter XII

VIRUS DISEASES OF COCOA*

The Viruses in West Africa: Symptoms—Rate of Spread—The Vectors—Virus-Vector Relationships—Alternative Hosts — Control Measures: Roguing Trials — Parasites and Predators — The Selection of Resistant Types — The Viruses in Trinidad: Symptoms—Rate of Spread—The Vectors—Control Measures—Conclusions.

VIRUS diseases of cocoa, commonly known in West Africa as "swollen shoot," have received attention only during the last fifteen years, although they have undoubtedly occurred unrecognized for much longer. From what is now known, it can be deduced that the earliest outbreak occurred between 1910 and 1915 in the Eastern Province of the Gold Coast, soon after cocoa farms were first established in that particular district (Nankese). The subsequent history is one of extensive cocoa planting, and of small scattered outbreaks of swollen shoot appearing over a wide area, sometimes as "satellites" to earlier outbreaks, but frequently isolated in otherwise healthy farms. Although many farms had been entirely destroyed by 1940, when the first evidence of its virus origin was obtained, most of the outbreaks were still discrete in the affected area of some 200 square miles. The merging of separate but expanding, more or less circular, outbreaks into larger irregular areas of dead and dying trees, with diminishing pockets of healthy cocoa, progressed rapidly during the war years to form what is now called "the devastated area."

Detailed surveys have shown that virus diseases of the swollen shoot type are widespread in scattered outbreaks throughout West Africa from Western Ivory Coast to Western Nigeria. They occur not only where cocoa is grown intensively with little shade, but also in heavily forested areas and even in small farms isolated in forest reserves. The viruses seem to be endemic in the local flora and to have spread to cocoa soon after the crop was extensively planted. Similar viruses, though less virulent, also occur in Trinidad and their

* Partly adapted from Dr. A. F. Posnette's paper presented to the 13th International Horticultural Congress, 1952.

resemblance to some of the West African strains suggests a common origin. Although not discovered until 1942, virus disease must have been present in the Northern Range cocoa estates for many years previously, and there is no evidence for or against either its introduction or its spread to cocoa from other plants.

Attempts to control swollen shoot by eradication have achieved some outstanding local successes in the Gold Coast, both in experiments and in field application, and there is no doubt that most outbreaks can be controlled if treated promptly.

THE VIRUSES IN WEST AFRICA

Symptoms

It must be stressed that not one, but many, viruses or strains are involved, and consequently symptoms vary considerably. The name swollen shoot was given because the swellings were the first, and for several years the only, symptom by which the disease was recognized. Some virus strains do not cause swellings, however, and leaf mosaic patterns of various types are more diagnostic and serve to distinguish different strains. The pattern is usually related to the veins, either as vein-banding (Fig. 76 (1)) or as angular chlorotic spots bordering veins (Fig. 76 (2)), rarely as inter-veinal bands (Fig. 76 (3)). Sometimes, however, the pattern occurs all over the leaf with no vein influence (Fig. 76 (4)). Some viruses also cause a red pattern in the young leaves before the "flush" has hardened (Fig. 76 (5)).

Variation in symptoms is due not only to virus strains but also to different stages of infection. The leaves of trees recently infected with the most virulent virus show clearing of the smallest veins; later-formed leaves develop mosaic patterns; banding of the larger veins predominates in the chronic stage.

The most important effects, namely root-killing, defoliation, dieback, and death of the tree, occur with the more virulent strains, but the milder strains sometimes reduce yield to a greater extent than they reduce vigour.

Rate of Spread

There are two types of spread which contribute to the destruction of large areas of trees—the sporadic and continuous formation of scattered outbreaks, each of one or two infected trees, and the gradual enlargement of these outbreaks by tree-to-tree spread. The incidence of both types varies greatly from farm to farm and from district to district, and there is a tendency for both to accelerate as the disease increases. The number of trees infected in single out-

breaks has been observed to increase about three times in three years, eleven times in five years, and eighty-eight times in seven years.

The rate of formation of new scattered outbreaks on some seventy acres increased in three years from ten to forty per annum, and to sixty-nine in the following five years. Infected trees were destroyed immediately each of these outbreaks was discovered, but the area was surrounded by heavily infected cocoa from which the virus could have spread.

The combined effect of both types of spread has been followed on a plot of eight acres since 1945, when 31 per cent of the 4,636 trees were infected; 92 per cent were infected by 1951, and the yield had fallen from 4,390 lb. to 601 lb.

These statistics cannot convey adequately the rapidity with which swollen shoot devastated hundreds of square miles of established cocoa, leaving villages derelict and hamlets abandoned. The disease gathers momentum each year and, although over 12½ million diseased trees have been cut down in the Gold Coast alone, this cannot be expected to have any appreciable effect on the rate of mass spread

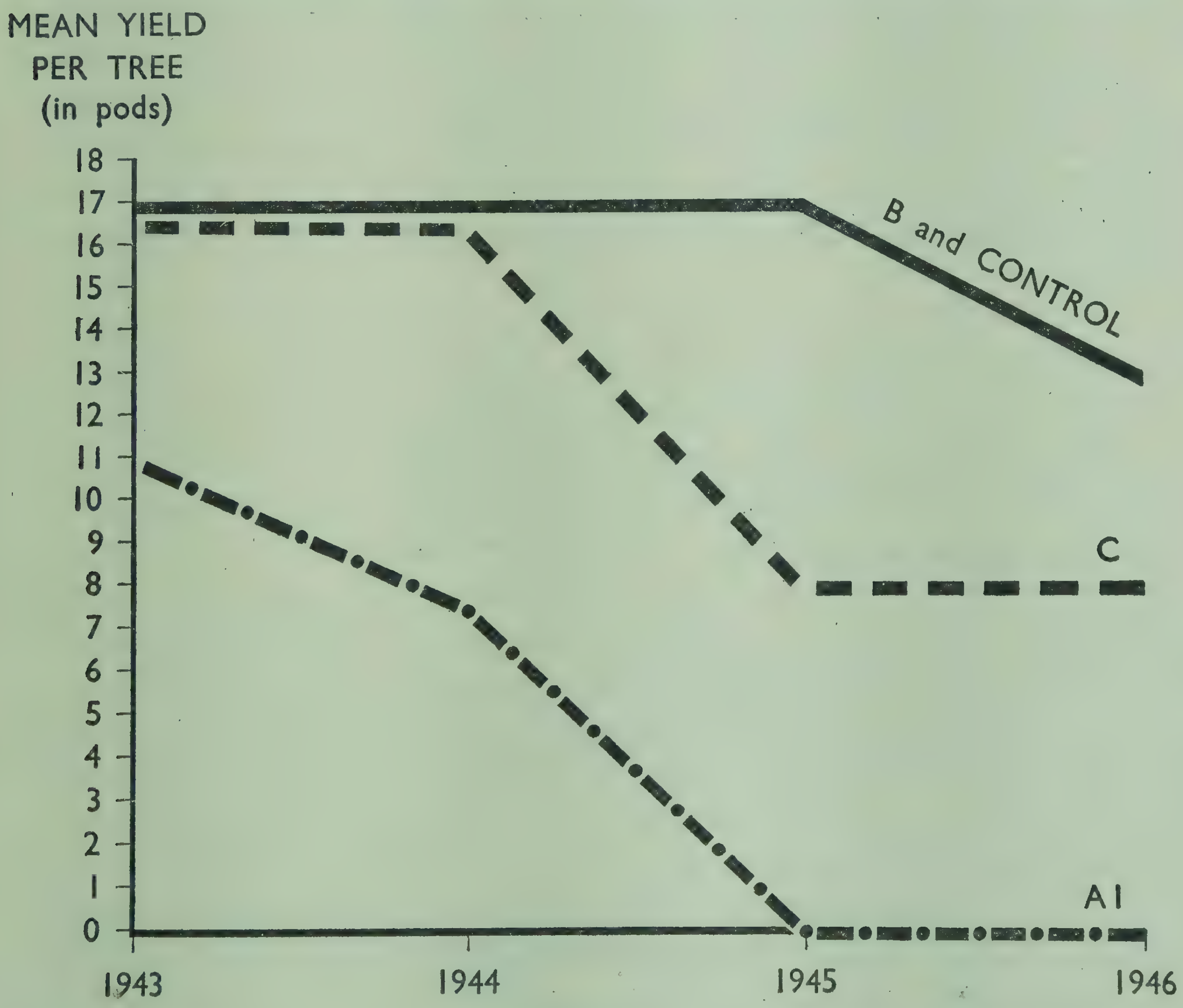


FIG. 8

EFFECT OF THREE VIRUSES ON YIELD OF TREES INFECTED IN 1942

because most of these trees were in the area already devastated and not at the perimeter, where large areas of healthy cocoa are threatened. The infected trees were destroyed chiefly to protect young cocoa which had been planted among the dying trees and was coming into bearing.

The Vectors

These cocoa viruses are unique in being carried by mealybugs. At least twelve species of Pseudococcid are known to transmit cocoa viruses in West Africa, but two species, *Pseudococcus njalensis* and *Ps. citri*, are so much more common than the rest that they are of paramount importance. These mealybugs feed on all aerial parts of the tree, but the majority are found on the young twigs in the foliage canopy. They prefer mature trees to young plants. *Ps. njalensis* is nearly always attended by Crematogaster ants which protect the mealybugs with "carton tents" and so render the conventional control measures ineffective.

Mealybugs are dispersed by ants, by wind, and by walking; man also helps in their dispersal, particularly on pods during harvesting.

These Pseudococcids, *Ps. njalensis* and *Ps. citri* in particular, feed on a wide range of plant species besides cocoa, this being another complicating factor in their control, since a cocoa farm is not a mono-culture like a fruit orchard, but a complex of species comprising high, medium, and low shade trees, shrubs, and ground herbage.

Virus-Vector Relationships

The feeding times required for mealybugs to become infective and to infect plants, and the length of time they remain infective have been investigated. The results can be summarized by saying that the vector requires several hours' feeding to become infective, but then transmits the virus in a matter of minutes. The virus persists only a short time (less than an hour) in the feeding insect, but when starved, the vector may remain infective for upwards of thirty-six hours. A single mealybug can infect a young plant, but not less than twenty-five are required to make almost certain that infection will occur.

Alternative Hosts

The important question of alternative hosts of the virus has been studied in two ways. In the laboratory, seedlings of the common forest trees and weeds associated with the cocoa, and of less common species in the *Sterculiaceae* and related families, have been subjected to infective mealybugs and later tested to find out whether or not

they have become infected with virus. In this way the following indigenous species have been shown to be susceptible:

STERCULIACEAE	BOMBACACEAE
Cola chlamydantha K. Schum.	*Adansonia digitata* Linn.
Cola cordifolia R. Br.	*Bombax buonopozense* P. Beauv.
Erythropsis barteri K. Schum.	*Ceiba pentandra* Gaertn.
Sterculia rhinopetala K. Schum.	TILIACEAE
Sterculia tragacantha Lindl.	*Corchorus tridens* Linn.
Pterygota macrocarpa K. Schum.	

The second approach has been to test, by mealybug transference to cocoa, plants suspected of being infected in the field. This method has been successful with *Cola chlamydantha*, many infected trees having been found both among cocoa trees and in forests far distant from cocoa. Infected *Ceiba pentandra* trees have also been found, but virus transmission from them to cocoa has proved difficult and is apparently a rare event in the field.

In most alternative hosts (*Cola chlamydantha* is one exception) the virus content seems to fall to a low level, or in some way to become unavailable to all but a few individual insects out of hundreds fed on the plant. Coppicing the plant has sometimes led to a temporary rise in virus availability, and it is suspected that severe damage, such as occurs in tornadoes or when one forest tree falls against another, may have this effect. New outbreaks of swollen shoot have frequently occurred on the site of fallen shade trees.

Sufficient definite information is now available to confirm that the swollen shoot viruses are indigenous to the West African flora, and the original hosts must be taken into account in planning both the control of the present epidemic and the future planting of cocoa.

Control Measures

The control of plant diseases in general is at present based on preventive measures. Although now being widely and intensively investigated, therapy has yet to be applied to plant diseases on a field scale. The control measures which have been applied or contemplated in West Africa are all designed to prevent the disease from spreading to healthy trees from infected ones.

Three principles are involved:

(1) The removal of the source of infection, i.e. the destruction of diseased trees.

(2) The destruction of the mealybug vector.

(3) The increased resistance of the healthy trees.

Roguing trials carried out since 1940 have shown that the prompt removal of infected trees while individual outbreaks are still small (less than fifty trees) is effective in stopping tree-to-tree spread. As might be expected, the larger the outbreak the more difficult it is to control. When over 30 per cent of the tree population in an area is infected, roguing alone is unlikely to have much immediate effect on the spread, probably because of the high proportion of latent infection among the apparently healthy trees. Supplementary measures must therefore be taken to stop the spread from these latent infections.

Removal of the first ring of symptomless trees around outbreaks greatly increases the efficiency of roguing. Coppicing the surrounding trees is also effective, since it not only removes the bulk of the mealybug population but also induces the trees with latent infection to develop symptoms rapidly on their sucker growth so that they can be distinguished from healthy trees and quickly destroyed.

Parasites and predators are also being tried as a means of reducing the mealybug population. Hymenopterous parasites and Coccinellid predators have been introduced, in collaboration with the Commonwealth Bureau of Biological Control, to supplement the indigenous enemies which are already keeping the mealybug population below the status of an economic pest.

The selection of resistant types of cocoa is the most attractive long-term solution to the problem. Local selection among surviving trees in devastated farms did not yield any promising material, but there is now some prospect that effective field resistance may be found among recent introductions from the Amazon region of Ecuador. It must be remembered, however, that genetical resistance will not help to save any of the existing cocoa population; only resistance of the acquired type can do that. Mild virus strains (propagated from the surviving trees in outbreaks) have been found to impart "resistance" against the most virulent strain. The use of these mild strains is still under investigation, and before they can be widely used the inherent dangers must be carefully considered. Unlike vaccination of animals against virus diseases, protective inoculation of plants results in a permanent infection throughout the life of the plant. Not only is the long-term effect of mild-strain infection on yield still unknown, but there is also danger of changes in virulence occurring by mutation. A further objection is that a mild strain of one virus will protect plants only against other strains of that virus and not against the many other viruses occurring locally in West Africa. Even if the most severe virus were controlled these other viruses would still present a serious problem.

THE VIRUSES IN TRINIDAD

Symptoms

Only two symptom types have been described in Trinidad. On the young leaves of most cocoa clones and seedlings "Strain A" causes a red mottle, usually in the form of broad bands along the main veins. Yellow flecks or transparencies are also formed at the sides of some of the veins and are still visible in the mature leaf. This virus also causes a red mottle on the pods of certain clones. "Strain B" is characterized by a clearing and extensive banding of the veins, the yellow bands being narrower than the flecks typical of "Strain A"; red mottling rarely occurs.

Swellings on the shoots, green mottling and dwarfing of the pods, and root necrosis—all symptoms of the most virulent virus strain in the Gold Coast—have not been reported in Trinidad. In this respect, and also in the absence of any distinction between acute and chronic symptoms, the Trinidad viruses resemble the West African virus 1C.

Rate of Spread

The spread of "Strain A" virus in plots of clonal cocoa at River Estate has been recorded for the years 1944–51. Removal of trees with symptoms up to 1946 may have reduced the rate of spread at first, but nevertheless the number of such trees increased from 57 in 1944 to 284 in 1947, and to 1,154 in 1951. In the same area, observations suggest that the virus weakens the trees and accentuates die-back, particularly in some clones. Statistical analysis of individual tree yields has shown that the crop is reduced in proportion to the duration of infection, at least for the first five years. The reduction is of the order of 6 per cent per annum, or about 30 per cent after six years' infection—an effect comparable with that reported for the "mild" strain 1C in the Gold Coast.

With the exception of an "escape," probably introduced in propagation material, in the Sangre Grande district of the Central Range, Trinidad cocoa viruses are still restricted to the Northern Range. To what extent they have spread along the range in recent years is not known, though they have been found farther and farther eastwards and, judging from their small size, outbreaks found in 1951 were of recent origin.

The Vectors

Like the swollen shoot viruses, the cocoa viruses in Trinidad are transmitted by mealybugs. Five species are known to be vectors, but because it occurs in greater numbers and is more active than the others, *Pseudococcus citri* is the species most responsible for spread in the field. Nymphs and young adults of *Ps. citri* are more active than those of *Ps. njalensis*, which does not occur in Trinidad, so that ant attendants are perhaps less important in virus-spread in Trinidad than in the Gold Coast.

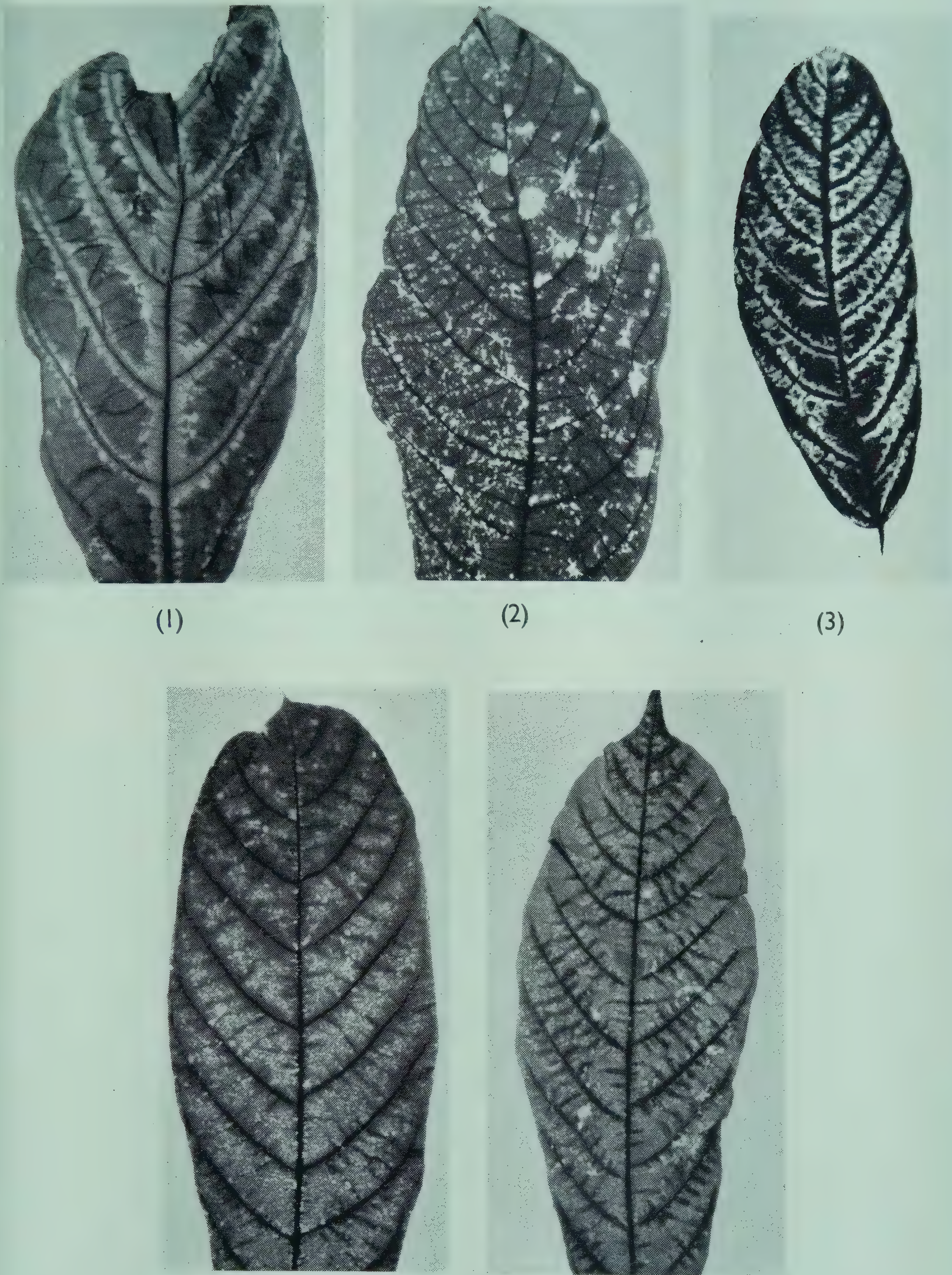
The vector relationships of the Trinidad viruses do not differ in any important respect from those of the West African viruses; such minor differences as have been reported can be attributed to the different feeding behaviour of *Ps. citri* and *Ps. njalensis* and to the different reaction of Trinitario and West African Amelonado seedlings.

Ps. citri is controlled by local parasites and predators in Trinidad, as is *Ps. njalensis* in the Gold Coast, so that it is not an economic pest except as a virus vector. The already high level of parasitism (and of hyperparasitism) suggests that further biological control by introduced parasites is unlikely to succeed to the extent of reducing virus spread.

Control Measures

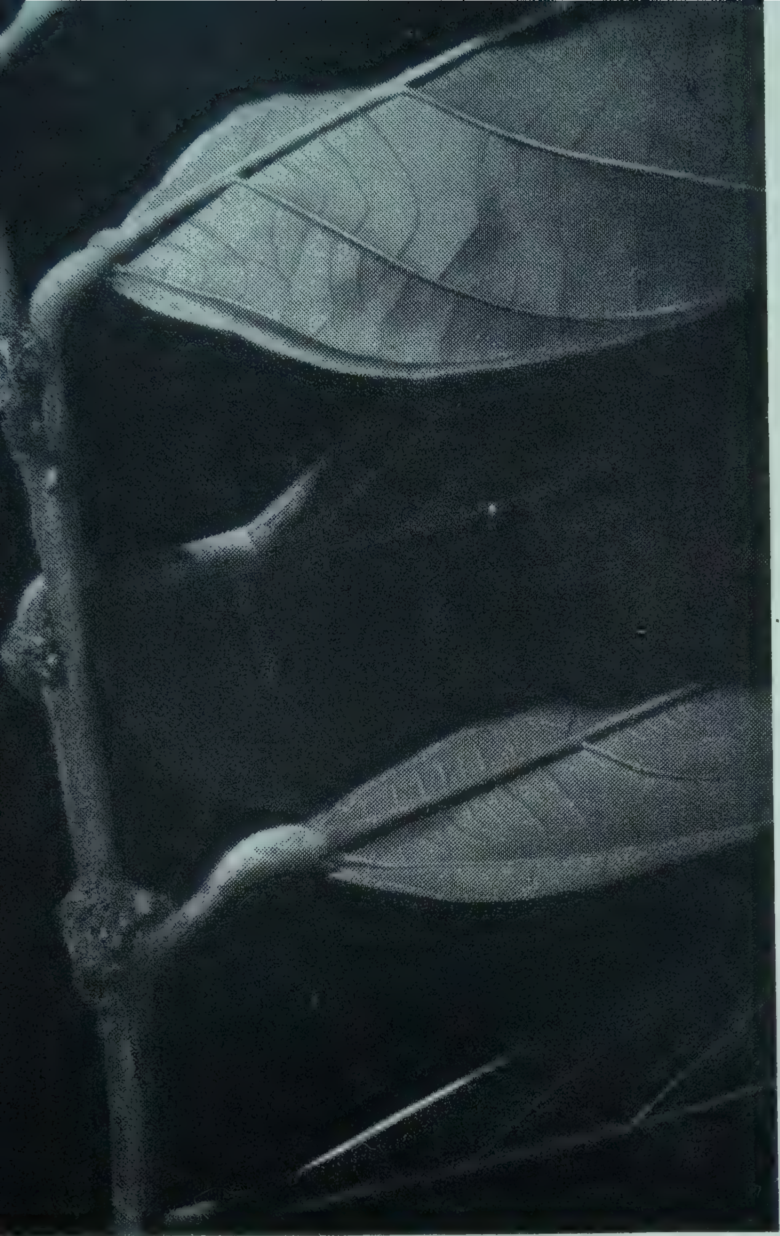
The principles discussed for the control of viruses in West Africa also apply in Trinidad but with changes in emphasis. The longer latent period in the tree makes the Trinidad viruses (and the mild West African viruses) more difficult to control by cutting-out than the virulent strain of swollen shoot in the Gold Coast. This difficulty is accentuated by the great variation between Trinitario seedling trees in their symptom-expression, as compared with the more uniform cocoa in West Africa.

This greater variation offers scope for the selection of resistant trees, but no differences in susceptibility between I.C.S. clones have yet been reported, and no trace of virus resistance has been found in the limited population of Trinidad type cocoa in the Gold Coast. Yet great differences in tolerance certainly exist and if natural spread is allowed to continue, resistant trees may yet reveal themselves.

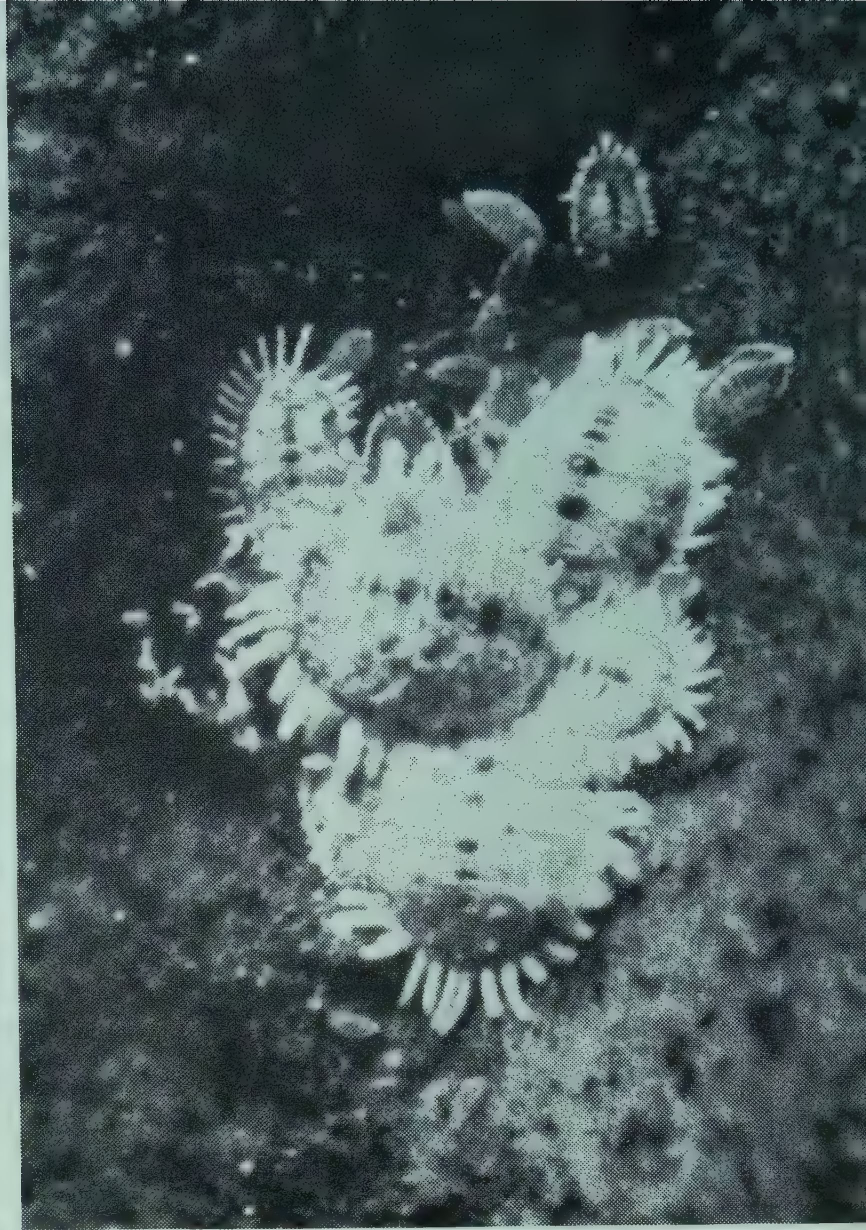


76. Leaf symptoms of swollen shoot

(1) Vein-banding on a young flush. (2) Angular chlorotic spots bordering veins. (3) Interveinal bands. (4) "Pepper and salt" mosaic. (5) Red vein-banding

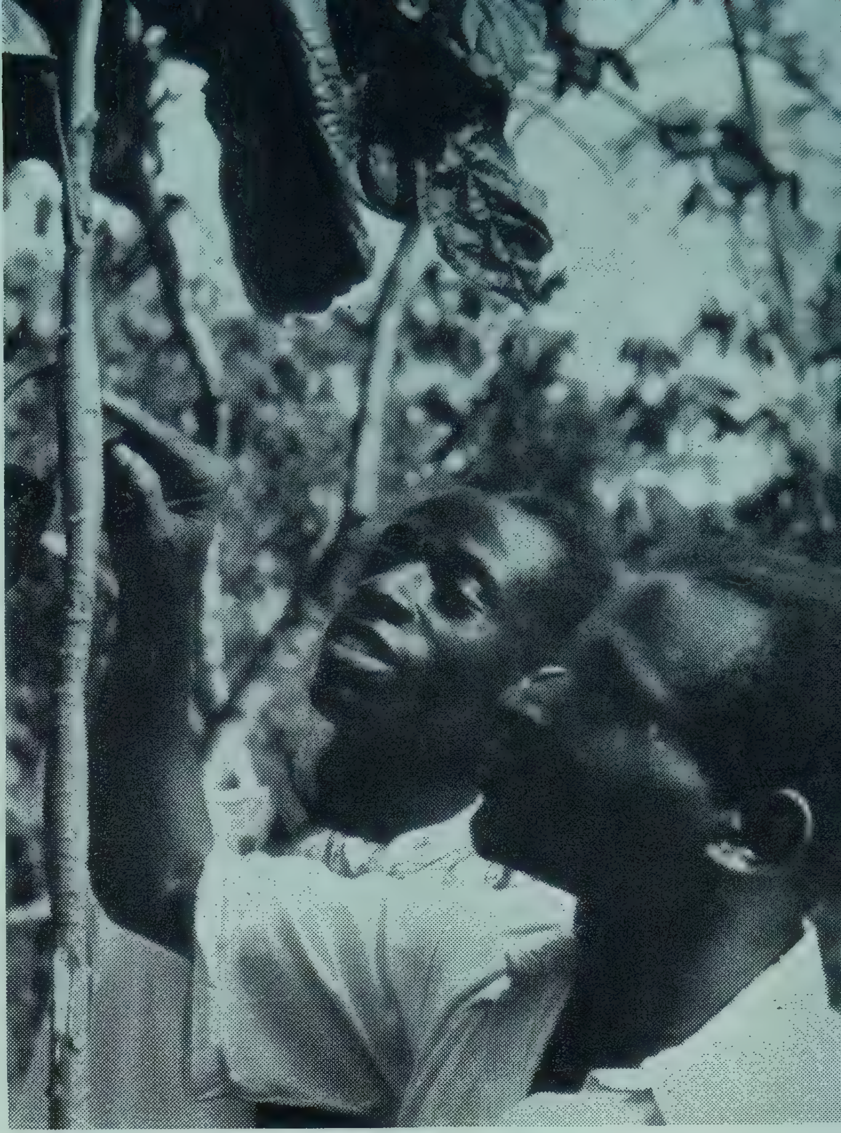


77. Mealybug tents on a cocoa stem



78. Adults and nymphs of the mealybug, *Pseudococcus njalensis*

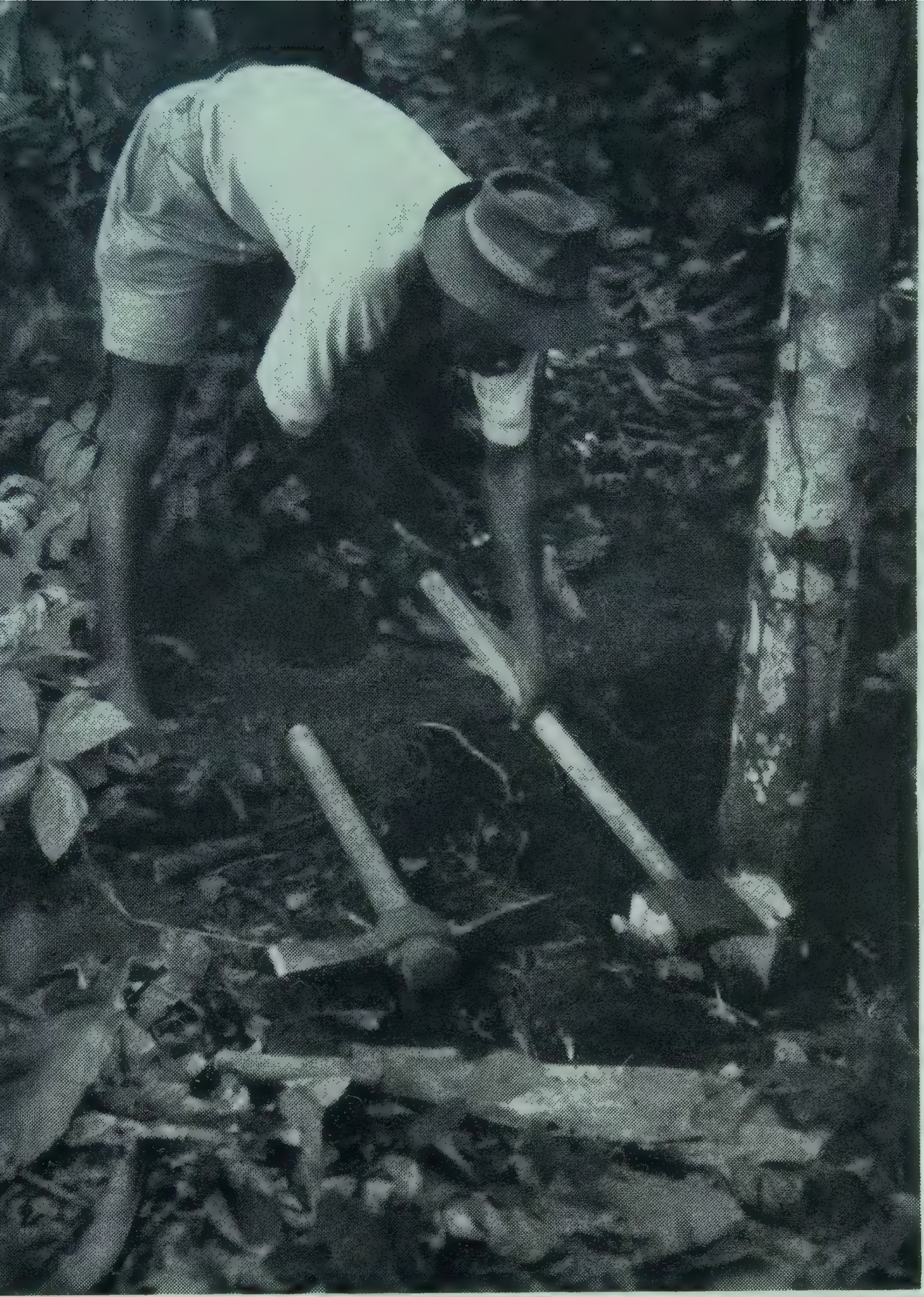
79. A large tented colony of mealybugs on a cocoa pod.
(Left): the tent unbroken. *(Right)*: the tent broken, showing mealybugs and ants



80. Mature silk cotton or kapok tree (*Ceiba pentandra*), about 150 feet high. This is an alternative host for swollen shoot virus

81. Typical swellings produced by swollen shoot virus

82. A broken canopy caused by an outbreak of swollen shoot



83. A diseased cocoa tree being cut out

84. A small outbreak of swollen shoot after cutting out. The trunks have been piled for inspection and counting so that compensation can be assessed

CONCLUSIONS

What damage are these virus diseases likely to cause in cocoa plantations in the future? It seems probable that the answer will be influenced mainly by two factors—vegetative propagation and geography. Vegetative propagation is the most efficient means known of distributing viruses, and a change from seedling to clonal production will, unless effective precautions are taken, increase the potential threat from virus diseases. There are two reasons for this: first, because all cuttings or budlings raised from an infected tree are infected, and the danger of masked or symptomless viruses being distributed in this way is very real; and, secondly, because the uniformity of clonal cocoa offers no genetical barriers to spread if a virus strain should occur to which the chosen clones are particularly susceptible.

It must be stressed that these dangers are not advanced as reasons why clonal cocoa should not be planted. They are, rather, reasons why vegetative propagation should be done with care to insure that only healthy material is used, and why suitable mixtures of clones should be planted instead of those with a preponderance of a few clones. Furthermore, with a crop like cocoa where absolute uniformity of the product is not required, may not be desirable, and in any case is practically unattainable (in the sense of having every bean alike), there is a strong case for the use of "clonal seed" when progeny trials have shown which clones are desirable parents.

It seems probable, however, that whatever means of propagating planting material are adopted in the near future, geography will continue to decide which areas suffer most from virus diseases. In West Africa, cocoa viruses are endemic in the local flora, where they are virtually beyond control. Even though the present epidemic in cocoa is eventually checked, viruses will continue to invade cocoa from wild hosts, and the amount of damage done will depend on how promptly and effectively control measures are instituted in each outbreak. There seems little doubt that the known cocoa viruses can now be controlled with relative ease (compared with the fungus diseases) provided prompt action is taken, and one can predict that, should any outbreaks occur in countries where virus diseases have not yet appeared, they would be controlled quickly before an epidemic on the Gold Coast (or even on the Trinidad) scale could develop. In the older cocoa-growing countries, such as those in South and Central America, it seems improbable that there are viruses in the local flora which can be transferred to cocoa by the existing

insects, and only in the event of the viruses or new vectors being introduced would virus diseases appear.

In new areas, where cocoa planting on an extensive scale is just beginning, forest trees may carry viruses which will eventually be transferred to cocoa, but unless they behave differently from the known cocoa viruses, they should not become a serious problem because, with our present knowledge, they should be detected and controlled at an early stage.

Only in West Africa, and perhaps in Trinidad, then, are virus diseases likely to be an important factor in future cocoa production, and in these areas much depends on whether the present epidemics can be brought under control. If this can be done, and the amount of infection reduced to only that coming into the crop from wild hosts, viruses may well become of minor economic importance. We can then look forward to the final assault on the citadel—the wild plants which harbour the viruses.

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Chapter XIII

COCOA GRADES AND GRADING

Types of Cocoa required by Manufacturers—Preparation and Quality—Defective Beans in relation to Grading—Standards set by some Importing Countries — Export Regulations in Producing Countries—Sampling—Percentage of Shell to Whole Bean.

MOST countries with large exports of agricultural produce have formulated grading regulations which classify products according to their quality. By avoiding the export of inferior qualities, it is possible to establish a good reputation in the export market. Buyers know what qualities to expect when purchasing the various grades, and whether or not these grades conform to the regulations of the importing country.

When the Americas, apart from Brazil, were the main suppliers of cocoa, the terms "fine" and "quality" were frequently used. These terms usually referred to a particular character or flavour, rather than to the quality of the beans in respect of their size, uniformity, butterfat content, or high standard of preparation. Flavour, as a character, was of more importance in the days when manufacturers had to rely on different flavours to make up a desired blend.

Criollos and allied types were the cocoas with distinctive flavours. Forasteros, of which Amelonado provides the bulk, have a relatively weak flavour. As Brazil and, later, West Africa, both of which grew large quantities of Amelonado, came to supply more and more of world needs, the U.S.A. and the U.K. became accustomed to the use of this basic type of cocoa.

For a time there was a keen general demand for "flavour" cocoas from the Americas, Ceylon, and Java, and high premiums were paid for these for the purpose of blending basic cocoas with them. But as the supply of basic cocoa mounted until it formed the overwhelming bulk of world supplies, "flavour" cocoas were used mainly to produce the required blends. Again, the increased supplies of basic cocoa coincided with the rise in popularity of milk chocolate for which the mild flavour of Amelonado cocoa is particularly suited. While premiums are still paid for some "flavour" cocoas, the de-

mand for these is mainly confined to certain European markets, and amounts to 10 per cent or less of all the cocoa produced.

Although the terms "fine" and "quality" are still retained in trade circles, cocoa is now mainly judged on its purity and freedom from defects.

TYPES OF COCOA REQUIRED BY MANUFACTURERS

When discussing types of cocoa, it is appropriate to quote a statement made on behalf of the British cocoa manufacturers at the Cocoa Research Conference held in London in 1945. It expresses the view of the manufacturers who buy the bulk of the world's raw cocoa and it has not since been modified:

> *Types of Cocoa*—The industry requires three types of cocoa, the first two types in comparatively less quantity and the third, for the bulk of the cocoa, in unlimited quantities.
>
> The first type would be true Criollo cocoa, i.e. a tree yielding plump seed, white or only pale lilac when in the pod and of a cinnamon colour when fermented.
>
> The second could be of the Trinitario type, with plump purple beans when in the pod and red-brown when properly prepared. Between the first and second types industry would require from 5 to 10 per cent of its requirements.
>
> The third, and this for the bulk of the industry's use, would be of the Amazonian-Forastero type commonly classed as Amelonado. The beans are deep purple in the pod, rather small and flattish, and when properly fermented a deep chocolate brown.
>
> The trees selected should be hardy, disease resistant, and provide a high yield of cocoa. The ability to stand drought may be of high importance in the cocoa-planting of the future.
>
> The character of the beans might well be considered along lines of ease of fermentation, probably bound up with the amount and nature of the pulp, high fat content, low bitterness, and a low caffeine-theobromine content.

This statement may be taken as a reliable guide by countries which contemplate new planting on a large scale or the extension of existing cocoa-growing areas.

PREPARATION AND QUALITY

The Cocoa, Chocolate and Confectionery Alliance have laid down the following standards for West African cocoa, the essential points of which apply to cocoas from other parts of the world:

Preparation

(*a*) Only beans from clean, well-grown, fully ripe and disease-free pods to be fermented.

(*b*) Using beans from freshly picked pods, the fermentation to be carried out under the best conditions possible, preferably in lots of not less than 400 lb. wet weight.

(*c*) During fermentation, the beans to be handled in such a way that the whole batch of beans is evenly fermented (over- and under-fermentation being equally avoided) and adequately aerated.

(*d*) Drying to be carried out immediately on the completion of the fermentation, and to be conducted in such a way as to be complete and uniform. At the commencement, drying should not be conducted too rapidly as otherwise the testa shrinks and adheres to the cotyledons.

(*e*) Drying to be carried out to such an extent as to ensure the proper keeping of the beans, care being taken that the beans at no stage thereafter become exposed to moisture or insect infestation.

Quality

(1) Beans prepared according to the above recommendations should have the following characteristics:

(*a*) They should be plump and of even size, of not less than 1 gram fermented dry weight.

(*b*) The shell should be loose and intact.

(*c*) The cotyledons should be friable, of open texture and chocolate-brown colour. On roasting they should develop the characteristic chocolate flavour.

(2) The following characteristics are undesirable:

(*a*) Beans affected by mould.

(*b*) Under-fermented beans having violet or slaty cotyledons.

(*c*) Beans affected by insect attack (weevil, etc.).

(*d*) Flat, immature, small and broken beans.

(*e*) Germinated beans.

DEFECTIVE BEANS IN RELATION TO GRADING

Grading, except where the term is applied to beans of different sizes in a sample, takes into account defects which influence the character and flavour of the finished product. Such defects are: mould, slatiness, grubs (i.e. insects), germination, and shrivelling.

Mould

Mould is much the worst defect as it renders the bean almost useless for manufacture. Its peculiar flavour persists and can be detected in the final product even when mould is present in a very small amount.

Beans may become mouldy at various stages of preparation and storage. It is found that only two or three kinds of mould are

capable of penetrating the unbroken shell, and the point of entry is where the radicle would emerge if the bean were to germinate; possibly the shell is weaker at this point, especially when the bean is about to germinate. When the more aggressive moulds have penetrated the shell, others will follow. Beans which have germinated, or which have been cut when the pod was being opened, readily acquire a mouldy condition. It is common to find moulds on the outside of the shell in the course of drying, especially in humid climates, but these moulds do not normally penetrate the shell unless the process of drying is unduly prolonged.

Slatiness

Slatiness is second in importance to mould. Slaty beans have either been insufficiently fermented, or dried without being fermented. They are recognized by their slaty-to-purple colour and are of a tough, leathery texture. Apart from the fact that slaty beans contain less butterfat than fermented beans, they do not have the characteristic chocolate flavour after roasting.

Grubby Beans

There are obvious objections to insects in any form in a foodstuff. Two major pests of stored cocoa are the moth, *Ephestia cautella*, and the beetle, *Araecerus fasciculatus*. The caterpillar of *Ephestia* will not penetrate an unbroken cocoa bean shell but *Araecerus* larvae can do so. Both are insects of the tropics but the former has adapted itself to life in temperate climates where it is a constant menace to cocoa and other stored food products. The Tobacco Beetle, *Lasioderma serricorne*, is known to have attacked stored cocoa in Nigeria, but was easily brought under control. The best way of reducing the incidence of insects in stored cocoa is to keep clean all buildings in the tropics where it is stacked and to insist on cleanliness in the holds of ships in which it is carried. A great deal of the infestation which occurs in imported cocoa takes place on board ship, especially where the cocoa is not carefully isolated from other products, such as groundnuts, which are themselves liable to infestation.

Germinated Beans

Germinated beans are regarded as defective because the hole in the shell through which the germ has pushed its way allows of the ready entry of insects and moulds.

Shrivelled Beans

Flat, thin, or shrivelled beans may contain little or no cotyledon and a high percentage of shell.

STANDARDS SET BY SOME IMPORTING COUNTRIES

In the U.S.A. there are regulations defining the quality of cocoa to be imported. The United States Pure Food Laws provide that cocoa shall contain not more than 10 per cent mould-plus-weevil, and not more than 5 per cent mould. The New York Cocoa Exchange provides for the following classes:

> Class 1. Slatiness not more than 10 per cent and all other defects not more than 8 per cent.
>
> Class 2. Slatiness not more than 10 per cent and all other defects not more than 15 per cent.
>
> Class 3. Slatiness more than 10 per cent but all other defects not more than 8 per cent.
>
> Class 4. Slatiness more than 10 per cent but all other defects not more than 15 per cent.

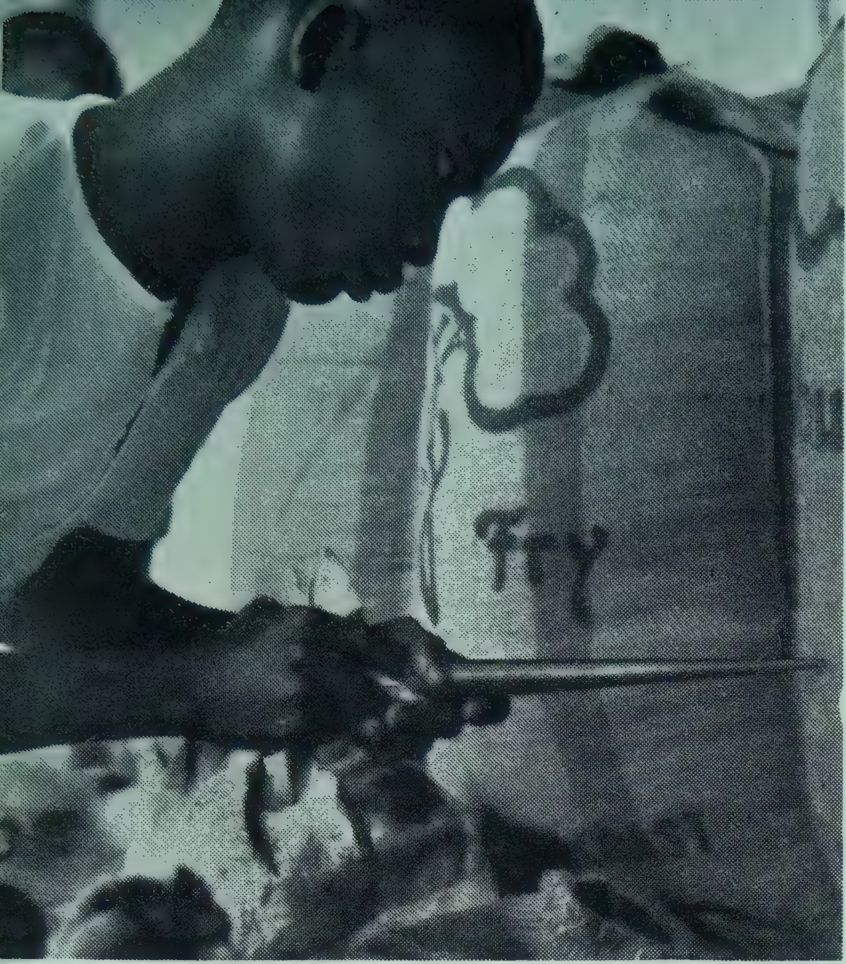
Cocoa with more than 15 per cent defects other than slatiness is non-tenderable by members.

In the United Kingdom there are no Government restrictions in respect of the quality of imports of cocoa. Cocoa is sold to manufacturers through brokers who belong to associations like the Cocoa Association of London. These have drawn up various types of contracts which, amongst other things, define the quality of the cocoa. Nowadays, cocoa is sold under a type of contract known as A.11. In this the clause defining quality states:

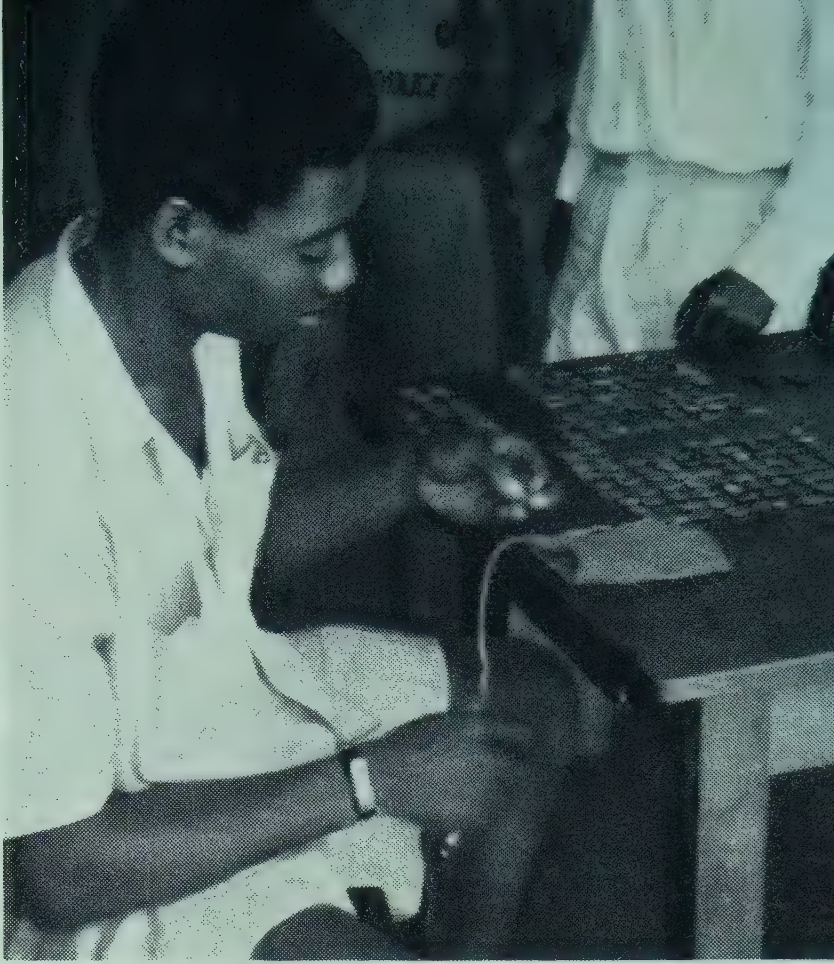
> Quality on arrival to be good fermented [or fair fermented]; if inferior thereto a fair allowance is to be made, in case of need to be settled by arbitration in London.
>
> Samples from not less than 30 per cent of the sound bags only, weighing approximately not less than 2 kilos. or 4 lb., shall be drawn and sealed promptly at the time of discharge in accordance with Clause 10.
>
> Buyers shall notify Sellers of any claim for inferiority of quality within 28 days of the final day of landing . . .

The quality stipulated is nearly always "good fermented," for which the limits are 5 per cent defective and 5 per cent slaty. The second grade in the United Kingdom is "fair fermented," with limits of 10 per cent defective and 10 per cent slaty.

In the United States "fair fermented" is the description applied to the Class 1 cocoa already defined—8 per cent defective, 10 per cent slaty.



85. A stab sampler being used to withdraw beans from sealed bags



86. A sample of beans being cut for grading at a buying station in the Gold Coast

87. Samples of cocoa being graded before shipment at Accra

88. Typical samples of beans, British West Africa

89. Typical samples of beans, Trinidad

90. Stored cocoa showing external and internal signs of damage by pests. (*Left*) the beetle *Araecerus fasciculatus*. (*Right*) the cocoa moth *Ephestia* sp.

EXPORT REGULATIONS IN PRODUCING COUNTRIES

Nigeria introduced regulations for grading cocoa in 1926 and the following are the grades now current:

Grade	*Unfermented*	*Defective*
1	less than 5 per cent	less than 5 per cent
2	less than 10 per cent	less than 10 per cent
3	less than 20 per cent	less than 10 per cent
4	no limit	less than 10 per cent

In 1947–48 a grading scheme was formulated which laid down price differentials for different grades of cocoa.

The payment of high prices for the better grades has had a remarkably good effect and has been instrumental in raising the standard of the cocoa exported from that country.

Grading is carried out by Government graders at certain specified buying stations up-country. The consignment to be sold is spread out and thoroughly mixed and a large sample taken. If it is found to contain quantities of foreign matter, grading is deferred until this has been removed. The sample is mixed and quartered, and then 300 beans are taken and weighed. The beans are cut through the middle lengthwise; one half is discarded and the other half is laid on a table for examination, and the percentage of unfermented and defective beans is assessed.

In the Gold Coast the grading standards are different from those in Nigeria, but only grades 1 and 2 are exported, the usable cocoa in the remainder being sold to the local cocoa butter factory.

The grades are:

Grade	*Slaty*	*Defective*
1 ..	not more than 5 per cent	not more than 5 per cent
2 ..	not more than 15 per cent	not more than 10 per cent
3 ..	no limit	not more than 15 per cent
Sub-grade	no limit	more than 15 per cent

SAMPLING

Sampling is carried out mainly on large consignments at ports of export or main buying stations. Samples are extracted from a limited number of bags by means of a stab-sampler, and the defects are assessed.

Bulk sampling by this method is an essential and valuable check on bagged cocoa, but it may be deceptive, as odd bags of bad cocoa in a large consignment may be overlooked.

Cocoa sampling cannot approach accuracy unless vast numbers of beans are cut. In West Africa there is often considerable variation in quality between bags and even within individual bags. Experience has shown that "There is no practicable method of sampling that can give a reliable estimate of the mean purity of each bag sampled." The "purity" is the percentage of good beans in a sample. A single sample gives a more accurate estimate of the purity of a consignment when the purity is high than when it is low. The estimate is also more reliable when the cocoa is uniform than when it is variable.

PERCENTAGE OF SHELL TO WHOLE BEAN

Manufacturers prefer supplies of even-sized beans because those differing widely in size are difficult to roast evenly. Small beans have a higher percentage of shell. In every sample the shell percentage does not vary directly with the size and weight of the bean. It generally remains fairly constant in beans weighing more than one gram, but below that weight the shell percentage rises rapidly. Beans of about ¾-gram in weight have a fat content as much as 5 per cent below that of the normal bean weighing more than 1 gram.

The chocolate industry is based on the availability of cocoa butter, and consequently the amount of fat in the nib is of primary importance to the economy of the industry.

The crop which is harvested in the Gold Coast and Nigeria in May–June is termed the "mid-crop" or "light crop," and the bean weight is usually a good deal below the average of that of the main crop which is harvested in October–January; main-crop beans generally weigh 11 ozs. or more per 300 beans.

The shell is a by-product of relatively low value and it is obvious that a high shell percentage is wasteful. The shell percentage of West African cocoa is around 11·5 per cent; some other countries have a higher and some a lower shell percentage.

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Chapter XIV

RESEARCH

The Historical Background—The Cocoa Research Conference of 1945—Research at the Imperial College of Tropical Agriculture—Research at the West African Cocoa Research Institute—Research in Other Parts of the World—Results of Research—Application of the Results of Research.

THE HISTORICAL BACKGROUND TO RESEARCH

IT has long been recognized that research is a necessary adjunct to plantation industries in the tropics. Although cocoa was one of the earliest of tropical crops to be laid out systematically in plantations, the need for research was not generally appreciated and in the early days provision for it was small. In this regard cocoa lagged behind such crops as rubber, tea and sugar, which for many years have possessed research organizations for the investigation of their problems.

In some of the countries where cocoa is grown, notably in the British West Indies, some useful work was carried out in the early days by the research staffs of the local departments of Agriculture, e.g. in Trinidad and some of the smaller islands. In West Africa however, where the major share of the world's cocoa is produced, little or no consideration was given before 1914 to the requirements of research. After that year some useful work was inaugurated by the Nigerian Department of Agriculture. Similar provision was not, however, made in the Gold Coast until 1938, when, following the recommendation of the Agricultural Adviser to the Secretary of State for the Colonies, a small cocoa experimental station was established at Tafo.

Since 1939 the increasing incidence of pests and diseases of cocoa both in West Africa and in the West Indies has necessitated increased attention to the need for research. In the West Indies the trouble was due to fungoid diseases, particularly witches' broom disease (*Marasmius perniciosus*), and in West Africa to the complex of virus diseases known as swollen shoot and to the attacks of capsid bugs.

In both regions the existence of the cocoa industry was seriously threatened.

In 1929 a small research scheme was inaugurated at the Imperial College of Tropical Agriculture in Trinidad, financed by contributions from the cocoa-producing colonies in the West Indies and West Africa and from cocoa manufacturing interests in the United Kingdom. It continued to operate until 1946 when it was superseded by the present larger scheme.

In West Africa the small research team at Tafo demonstrated the seriousness of the threat to the cocoa industry of the Gold Coast.

The dangers of the situation in the Gold Coast and the alarming speed with which large areas were being devastated by disease moved the Secretary of State in 1943 to depute his Agricultural Adviser, at that time Dr. (now Sir) Harold Tempany, to visit the Gold Coast to report on the position and indicate how to deal with it.

As a result it was decided that, despite the fact that the last war was then at its height, the West African cocoa industry should be safeguarded and the provision for research should be strengthened immediately. It was shown at that time that the disease of swollen shoot existed in the neighbouring territory of the Ivory Coast, and its presence was suspected in Nigeria. It was decided that surveys to ascertain the exact extent of the occurrence of the disease should be instituted without delay.

Accordingly the West African Cocoa Research Institute was organized, on an *ad hoc* basis in the first instance, making use of such staff and resources as were immediately available. Surveys revealed that the disease existed in the greater part of the Gold Coast and also in Nigeria, although the areas of really serious damage were mainly confined to the Eastern Province of the Gold Coast. In due course the Research Institute was placed on a permanent footing as a West African organization, with a Committee of Management under the chairmanship of the Secretary of the West African Governors' Conference.

Subsequently the Secretary of State for the Colonies set up in London, as a sub-committee of the Colonial Research Committee, a Cocoa Research Committee composed of scientists and persons closely acquainted with cocoa-growing, for the purpose of advising on cocoa research throughout the British Colonial Dependencies.

THE COCOA RESEARCH CONFERENCE OF 1945

At the instance of this Committee the Secretary of State convened a Cocoa Research Conference in London in 1945 with the object of

examining the whole field of research in relation to cocoa, having regard to the increasing demand for the product and the fact that existing sources of supply were declining. Its deliberations covered every phase of cocoa production and reviewed the existing provision for cocoa research throughout the Colonial Empire. It also defined the lines which research should follow in future, and made recommendations for research programmes in the West Indies and West Africa. These recommendations are still being followed.

The conference also drew the distinction between long-range research such as must be carried out by the cocoa research institutes, and short-range research which is carried out mainly by the local departments of agriculture. In addition, there remained certain lines of research which must be carried on with the assistance of other Departments of Government or by other research institutes in the colonies, or by research organizations of the Department of Scientific and Industrial Research in the United Kingdom.

In addition, the conference stressed that co-ordination of all forms of cocoa research in the British Commonwealth should be the function of the Cocoa Research Committee in London, and that there should be interchange of information between British workers and similar workers in foreign cocoa-producing countries.

RESEARCH AT THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

Owing to limited staff, the earlier work at the College was restricted in range, but gave valuable results and provided a foundation for more comprehensive investigations in the future. As a result of the recommendations of the Research Conference, a new scheme was devised on a much enlarged scale, financed jointly by H.M. Government under the Colonial Development and Welfare Act and by the Cocoa, Chocolate and Confectionery Alliance (representing manufacturers in the United Kingdom). The scheme was designed for the ten-year period 1946–56 and the cost, which was shared equally between H.M. Government and the Alliance, amounted to £312,000 for capital and recurrent expenditure. The full-time research staff of the scheme was enlarged to 11 members, while several members of the regular staff of the college also took part in the work. New laboratories and housing accommodation for the staff were erected. River Estate was acquired by the College through the generosity of Messrs. Cadbury Brothers Ltd. in order to provide land suitable for experimental work.

The programme of work under this scheme fell into five sections:

(1) Selection, breeding and propagation of cocoa.

(2) Soils and nutritional factors in relation to cocoa-growing.
(3) Other environmental factors in relation to cocoa-growing.
(4) Pests and diseases of cocoa.
(5) Preparation and quality of cocoa.

RESEARCH AT THE WEST AFRICAN COCOA RESEARCH INSTITUTE

The work of the Tafo station in the early days, when it was still a part of the Gold Coast Department of Agriculture, had already shown that the disease known as "swollen shoot" was in reality caused by virus infection, instead of being, as was formerly supposed, a physiological malady. When the West African Cocoa Research Institute was organized in 1944 it took over the buildings and staff of the existing station and the cadre of research officers was extended by secondment of officers from other colonies and a few new appointments. Owing to war conditions at that time, research staff was extremely difficult to obtain, a difficulty which persisted long after the end of the war. At the 1945 Cocoa Research Conference the research staff requirements were tentatively laid down as 27 officers including a director, a Principal Research Officer, a secretary and 24 research officers. Considerable additions were made to the accommodation at the Station, additional laboratories and other working buildings were erected, as well as quarters for the staff, etc. The small area of 50 acres of cocoa land, which was the total area available originally for experimental work, was enlarged by the acquisition of an additional 600 acres; a number of sub-stations representative of conditions at various points in the Gold Coast and Nigeria were also acquired.

Funds for the establishment and working of the new organization were provided by means of a grant of £1,000,000 from the Cocoa Marketing Boards of the Gold Coast and Nigeria.

The programme of research work laid down by the 1945 Cocoa Research Conference for the Institute included the following items. It has been followed closely since.

(1) The establishment at Tafo of collections of species and varieties of Theobroma.
(2) The selection and propagation of cocoa.
(3) The investigation of the factors controlling the economic life of the cocoa tree.
(4) The investigation of cocoa soils and the nutrient and climatic requirements of the cocoa tree.
(5) The investigation of the diseases and pests of cocoa in West Africa and methods for their control.

RESEARCH IN OTHER PARTS OF THE WORLD

Of recent years provision for cocoa research in non-British cocoa-growing countries has also considerably expanded. To-day there are research institutes wholly or partially devoted to the needs of cocoa in Brazil, Dutch Guiana, Costa Rica, French West Africa and the Belgian Congo. In Colombia, Ecuador, Guatemala, Mexico and Haiti there is also provision for research on cocoa.

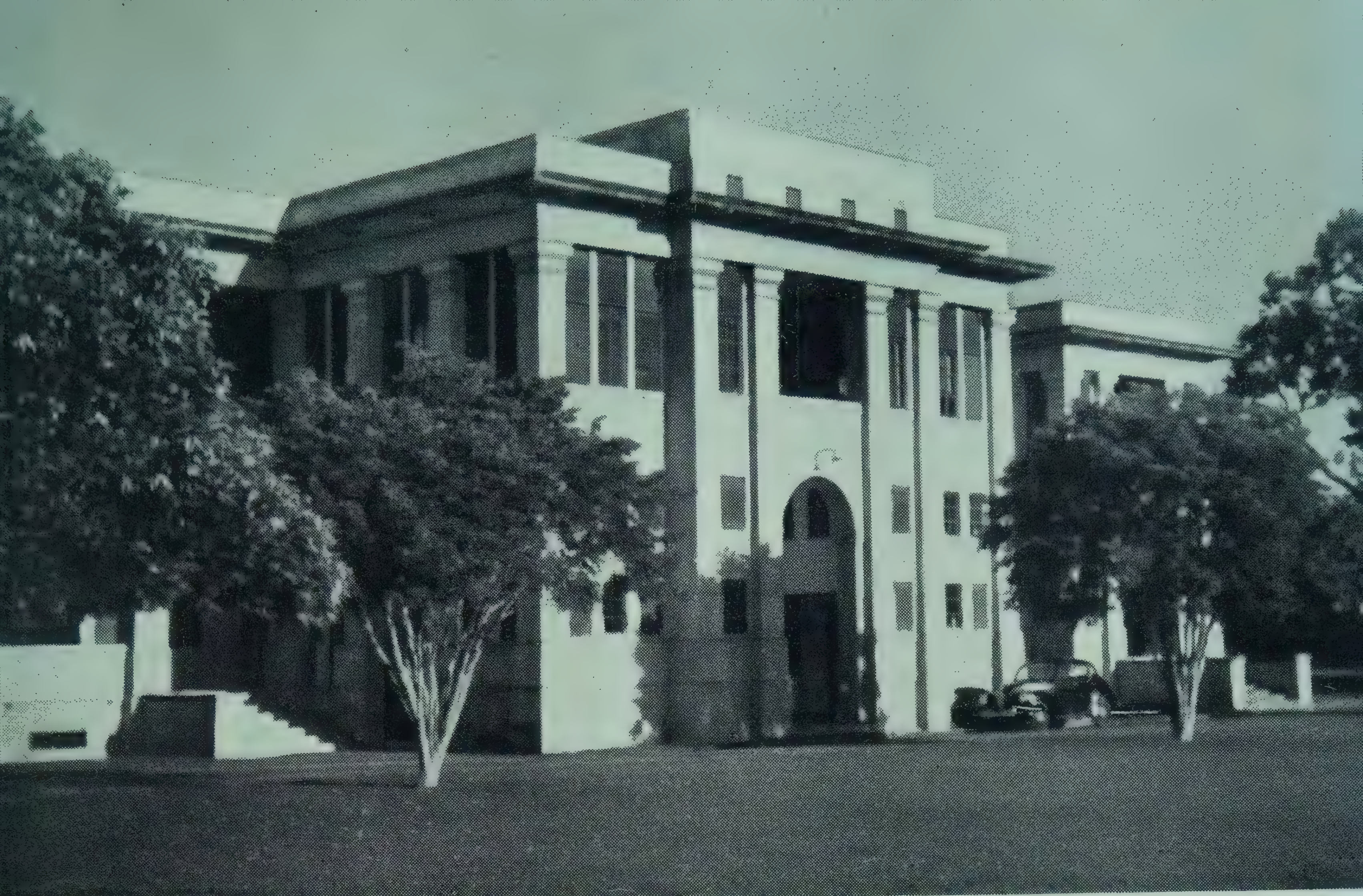
The most important development is probably at Turrialba in Costa Rica where the Inter-American Cacao Research Center was established in 1947 by the Technical Cacao Committee of the Economic and Social Council of the Organization of American States, as part of the Inter-American Institute of Agricultural Sciences located at the same place.

The Cacao Research Center is supported by a grant from the American Cocoa Research Institute—a non-profit making organization supported by the chocolate industry of the United States of America, the aim of which institute is to improve cocoa production in the Western Hemisphere and throughout the world. It is also supported by the revenue derived from a cocoa farm of 200 acres made available by the United Fruit Company. The institute possesses a small staff of trained scientists, and its work, in addition to research, includes the training in cocoa husbandry of students drawn from various cocoa-growing countries in the South and Central American region.

Its research programme has been deliberately directed towards the solution of short-term problems of immediate practical importance, the idea being to leave the problems of longer range to the older and larger research centres in Trinidad and West Africa.

THE RESULTS OF RESEARCH

In Trinidad, both at the Imperial College of Tropical Agriculture and also at the Trinidad Department of Agriculture, efforts have been chiefly concentrated on evolving strains of cocoa resistant to witches' broom disease and capable of giving higher yields than the cocoa at present cultivated. Scientific expeditions have explored the forests of the Amazon for new biotypes of Theobroma which could be used in breeding programmes. Breeding and selection work leading to the evolution of new types of cocoa and new techniques of propagation have been carried out. It has been possible through the support given by the Trinidad Cocoa Board to initiate a campaign for the rehabilitation of the Trinidad cocoa industry.



91. Imperial College of Tropical Agriculture, Trinidad

92. Cocoa fields in Grenada. Two fields can be seen surrounded by tall windbreaks

93. West African Cacao Research Institute, Tafo, Gold Coast

94. Cocoa awaiting shipment on the beach at Winneba, Gold Coast

95. Surf boats loaded with cocoa leaving the beach at Accra, Gold Coast

96. A lorry loaded with cocoa on its way from a Gold Coast buying station to rail-head

97. Cocoa being loaded into lighters prior to shipment at Takoradi, Gold Coast

At Tafo in the Gold Coast the major achievement is the elucidation of the complex story of the virus which attacks cocoa in that region, the discovery of its mode of transmission, the identification of, at any rate, some of the more important alternative wild hosts of the disease, the recognition of the various strains of the virus, and the evolution of a method of control of the disease by roguing, i.e., cutting out of diseased trees.

At both Centres results of considerable importance are expected in due time from the following: soil and fertilizer experiments; control of capsid bugs by the use of the newer chlorinated hydrocarbon insecticides such as DDT and B.H.C.; control of black pod disease by the use of sprays.

In all these and many other directions developments may be expected from the application of the results of research and it is therefore of paramount importance that provision for research should continue to be made on an increasing scale. Experience with plantation crops has shown that there is a constant and ever-present need for research.

Research has helped so far to ward off dangers which threatened with extinction the cocoa industry in two quarters of the world. It is to be hoped that motives of false economy may not engender a tendency to reduce such expenditure in the future.

THE APPLICATION OF THE RESULTS OF RESEARCH

Planters are at times inclined to be critical of research workers on the ground that the answers they supply to problems are academic and uneconomic or impracticable to apply. Equally, scientists are sometimes critical of planters for their unresponsive attitude to the recommendations offered.

Success in the application of research must therefore depend in the first instance on the testing of the results of small-scale scientific experiments on a field scale. It must further depend on close collaboration and confidence between the planter, the professional agriculturist, the research worker and manufacturing interests.

Increasing attention has of late years been paid to extension methods in many countries, and to the best technique to be adopted in conveying the results of research to the planters. This is particularly important in places like West Africa where the planting body is composed of African small-holders.

The series of international conferences organized by the Cocoa, Chocolate and Confectionery Alliance in London provide an opportunity for representatives of manufacturers to meet representatives

of the research workers and officials of the various governments in cocoa-growing countries, and to discuss the most recent developments in regard to the cocoa industry. There is no doubt that these gatherings serve a most useful purpose and help to promote mutual understanding of the problems involved and the results achieved.

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Chapter XV

WORLD PRODUCTION AND CONSUMPTION

A Factor Restricting Consumption—Importance of Price in World Markets—Price Fluctuations and their Effect—Marketing in the Gold Coast and Nigeria—Growth of World Production—The Rise in Production in West Africa and Brazil—Limitations to Expansion in West Africa—Distribution of World Production—Effects of Prices on Planting—New Growing Areas—Effect of Improved Cultural Methods—Cocoa Products—Local Processing—World Consumption—Consumption in U.S.A.—Consumption in U.K.—Consumption Elsewhere—Conclusion.

THE information which has been accumulated in recent years as regards the production capacity of most cocoa-producing countries, and the statistics now available, make it practicable to review the production and consumption of cocoa with greater knowledge than was possible in the past.

Like so many other tropical crops grown mainly for export, cocoa production has had its vicissitudes, some of which brought ruin and distress to the producers. But it may be said with confidence that the prospects for the future are better than ever they were since cocoa became a product of major importance in world markets.

Paul Bareau in a short survey, *Cocoa: A Crop with a Future*, discusses the cocoa industry with special reference to production and consumption.

The Cocoa, Chocolate and Confectionery Alliance has arranged international conferences in London for a number of years. These provide a means for exchange of information between manufacturers on the one hand and producers, scientists, and agriculturists on the other, and the printed Reports provide information on practically every aspect of the industry.

The general conclusion arrived at in these discussions on production and consumption is that the future prospects for the sale of raw cocoa in world markets are good. The danger of cocoa prices falling again to the ruinously low levels of the late 1920s and early 1930s is remote. A profitable price is envisaged for the foreseeable future.

In recent months, the price has reached an all-time record, and the world demand shows no sign of shrinking; in fact, the fear was expressed at a conference in London in 1954—convened by the Office International du Cacao et du Chocolat—that the shortage might lead to the adoption of synthetics and substitutes.

A FACTOR RESTRICTING CONSUMPTION

The high price of cocoa has restricted consumption of cocoa products in the world's largest market—the United States of America. This restriction has taken place notwithstanding the fact that there has been a large and steady annual increase in population in that country, and that prosperity has been at a very high level there in recent years. The restriction, or lack of expansion, of its cocoa market is due to keen competition by manufacturers for an inadequate supply of the raw material and the resultant high price of the finished product to the consumer. The remedy for this unfavourable situation lies in the production of more cocoa at a price which will enable manufacturers to market the final product at a price which will be conducive to greater consumption.

The present extremely high price of raw cocoa in world markets is not due to increases in costs of production but to keen competition for a scarce commodity.

IMPORTANCE OF PRICE IN WORLD MARKETS

The price level of raw cocoa and of its end-products is a matter of vital concern both to the grower and the manufacturer, and price levels which provide a reasonable margin to both parties are essential for the well-being of the industry as a whole. It is possible that some cocoa growers who suffered from low prices twenty years ago may be inclined to doubt whether the manufacturers have fully appreciated the importance of a profitable price to the grower, but the following may be taken as a reliable guide to the views of responsible manufacturers on this subject in recent times.

At the International Cocoa Conference held in London as long ago as October 1946, and attended by representatives of the main manufacturing concerns and cocoa-producing countries, the following resolution was passed unanimously:

> This Conference expresses the belief that the world demand for raw cocoa exceeds the available supply and attaches urgency to the increasing of supplies, and is of the opinion that any efficient new production which may be practicable for the next twenty-five years in existing or new areas will be absorbed at a fair price to the growers.

At a meeting of a special committee of the Inter-American Economic and Social Council in January 1947, the President of the Association of Cocoa and Chocolate Manufacturers of the United States expressed the view that the extremely low prices of the middle 'thirties were not desirable, even from the point of view of processers. He implied that such prices tended to retard the natural expansion of cocoa-growing, an expansion which was necessary for an increase in the use of chocolate products in the United States.

PRICE FLUCTUATIONS AND THEIR EFFECT

Uncertainty as regards seasonal supplies, and consequent speculation, give rise to fluctuations in world prices. Average yearly cocoa prices fluctuated from 13 to 7·6 cents per lb. in 1920–23; it was 15·8 cents per lb. in 1927, 4·4 cents in 1932 and 1933, and about 40 cents in 1947. The great variation in the amounts of annual output is mainly due to the incidence of disease, especially fungus disease, which fluctuates with variations in rainfall. As it has not yet been possible to forecast in advance the extent to which rainfall or less important factors will affect the output, this uncertainty is likely to remain.

Fluctuations in world market prices from year to year and during crop seasons have been, and still are, the bugbear of the grower and the manufacturer alike. Manufacturers and others involved in the financing of cocoa are concerned with finding the money to buy cocoa at the various price levels. The money at stake when cocoa prices are at high levels is very great, and even in the 1930s, when prices of raw cocoa were much lower, rapid changes in price brought ruin to some of those concerned in its purchase.

MARKETING IN THE GOLD COAST AND NIGERIA

In 1938 a Commission on the marketing of West African cocoa made certain recommendations for setting up a marketing organization, but no action was taken in regard to buying or selling the crop until war conditions in 1939–40 made necessary certain changes in the system which operated previously. From the time raw cocoa became an important commodity in West Africa, it was purchased and exported by merchant firms with representatives on the Coast, but in 1939–40 the Ministry of Food created an organization under the auspices of the Colonial Office, known as the West African Cocoa (Produce) Control Board, which concerned itself with

the purchase and sale of cocoa, with the Ministry of Food as the sole British customer.

In 1947 Marketing Boards were set up. The merchant firms now act as buying agents for the Board and the latter is responsible for export and shipment and for disposal of the produce; subsidiary companies in London sell the cocoa on world markets.

Important features of the Marketing Board from the point of view of the grower are that the price to be paid for the crop in any one season is declared at the beginning of the season, and a part of the accumulated profits are set aside to enable the Board to pay the farmer an economic price in the event of world prices falling to a low level.

TABLE A

WORLD PRODUCTION OF RAW COCOA

(*in thousand Long Tons*)

Year	*Annl. Prod.*	*5-year Avge.*	*Year*	*Annl. Prod.*	*5-year Avge.*	*Year*	*Annl. Prod.*	*5-year Avge.*
1900	101		1920	369		1940	670	
1901	106		1921	387		1941	654	
1902	125		1922	404		1942	662	
1903	126		1923	449		1943	601	
1904	149	121	1924	500	422	1944	554	628
1905	144		1925	488		1945	614	
1906	147		1926	470		1946	618	
1907	148		1927	481		1947	669	
1908	189		1928	506		1948	615	
1909	201	166	1929	529	495	1949	752	654
1910	217		1930	479		1950	766	
1911	236		1931	524		1951	780	
1912	227		1932	549		1952	680	
1913	249		1933	617		1953	735	(*740*)
1914	273	240	1934	580	550			
1915	292		1935	691				
1916	292		1936	725				
1917	343		1937	746				
1918	270		1938	717				
1919	463	332	1939	787	733			

Figures for 1900–1930 are taken from *The Gordian*; those for 1930–1946 from the paper given by L. A. Byles at the 1951 London Cocoa Conference, and those for 1947–1953 from S. L. Hale's paper at the 1953 Conference.

GROWTH OF WORLD PRODUCTION

From a position of relatively minor importance at the beginning of the twentieth century, the cocoa bean began its meteoric rise in the first quarter of the century and in due course achieved the position of major importance since maintained. In 1900 production was about 100,000 tons and by 1910 it was 200,000 tons. During the years 1918 to 1923 average production was 395,000 tons per annum, rising to an average production of 692,000 tons between 1934 and 1939. Since that time annual production has fluctuated between the low war-time figure of 554,000 tons and the average of some 750,000 tons per annum of recent years. From the point of view of rate of progress, the relatively low production during certain years of the Second World War is not significant, as it was brought about through lack of transport and other causes not connected with conditions of disease or climate.

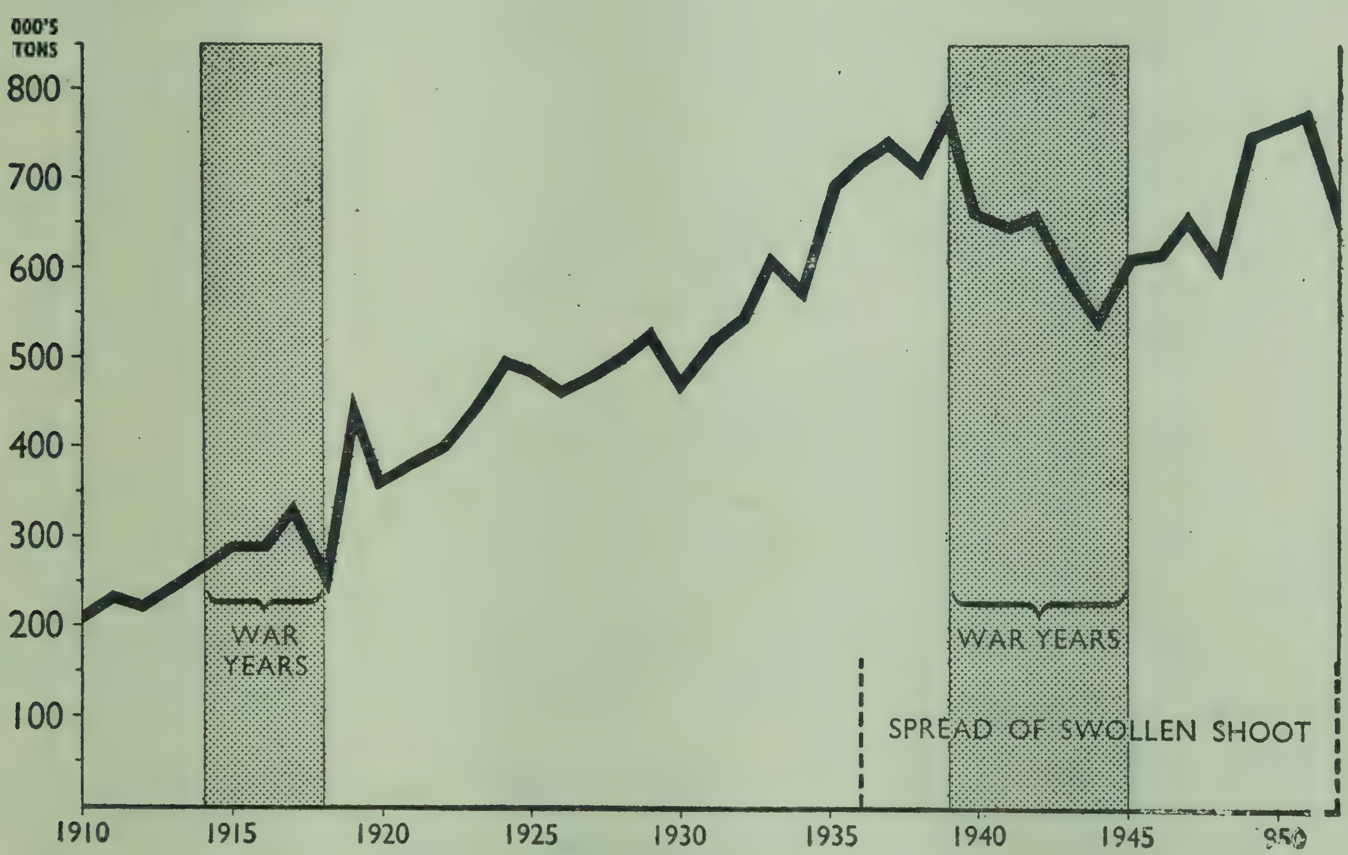

FIG. 9

WORLD OUTPUT OF COCOA, 1910–50

THE RISE IN PRODUCTION IN WEST AFRICA AND BRAZIL

The main contributors to the rapid rise in production were West Africa and Brazil. While the output of many of the original cocoa-exporting countries declined, West Africa and Brazil consistently showed a rapid increase in output until the 1920s, since when the rate

of increase has been slow or negligible. The rapid rise in production was due to the introduction of cocoa to West Africa where a large population of peasants were able to plant great areas in a short time under favourable conditions of soil and climate. In the State of Bahia in Brazil, small-holders and estates with similar favourable conditions also achieved remarkable increases.

The spectacular rise in importance of Africa as a producer may be appreciated when it is realized that in 1900 America produced 81 per cent and Africa 16 per cent of the world's cocoa. For the past twenty years Africa has produced 65 per cent and America, including the West Indies, about 34 per cent.

LIMITATIONS TO EXPANSION IN WEST AFRICA

The slowing-down of the upward trend in production in some of the producing countries in West Africa was due to the fact that where cocoa was widely-grown by village communities their best soils were in due course fully occupied, and although there was migration to unoccupied land and further extensive planting, production from new areas was offset by the ravages of pests and diseases. Periods of low prices retarded the rate of new planting, and general progress in diverse directions in these countries made other calls on the available labour.

DISTRIBUTION OF WORLD PRODUCTION

The bulk of the world's cocoa comes from the Gold Coast, Brazil, and Nigeria, and from French West African Territories which include the Ivory Coast and French Cameroons. The Gold Coast tops the list with about 230,000 tons, and the others each produce 50,000 tons or more. (French Togoland has an output of some 5,000 tons.)

The Dominican Republic and Ecuador are next in importance, each with an annual production of over 25,000 tons.

Venezeula, Fernando Po, São Tomé, Colombia, and the British West Indies, each with a production of 10,000 tons or more, account for between 60,000 and 70,000 tons.

The remaining countries between them produce about 40,000 tons, Mexico and Costa Rica being the most important in this group.

The pattern of production in the near future seems unlikely to change to any appreciable extent, as the conditions which led to the spectacular advances in production in West Africa cannot be repeated in other countries.

PRINCIPAL COCOA-GROWING AREAS

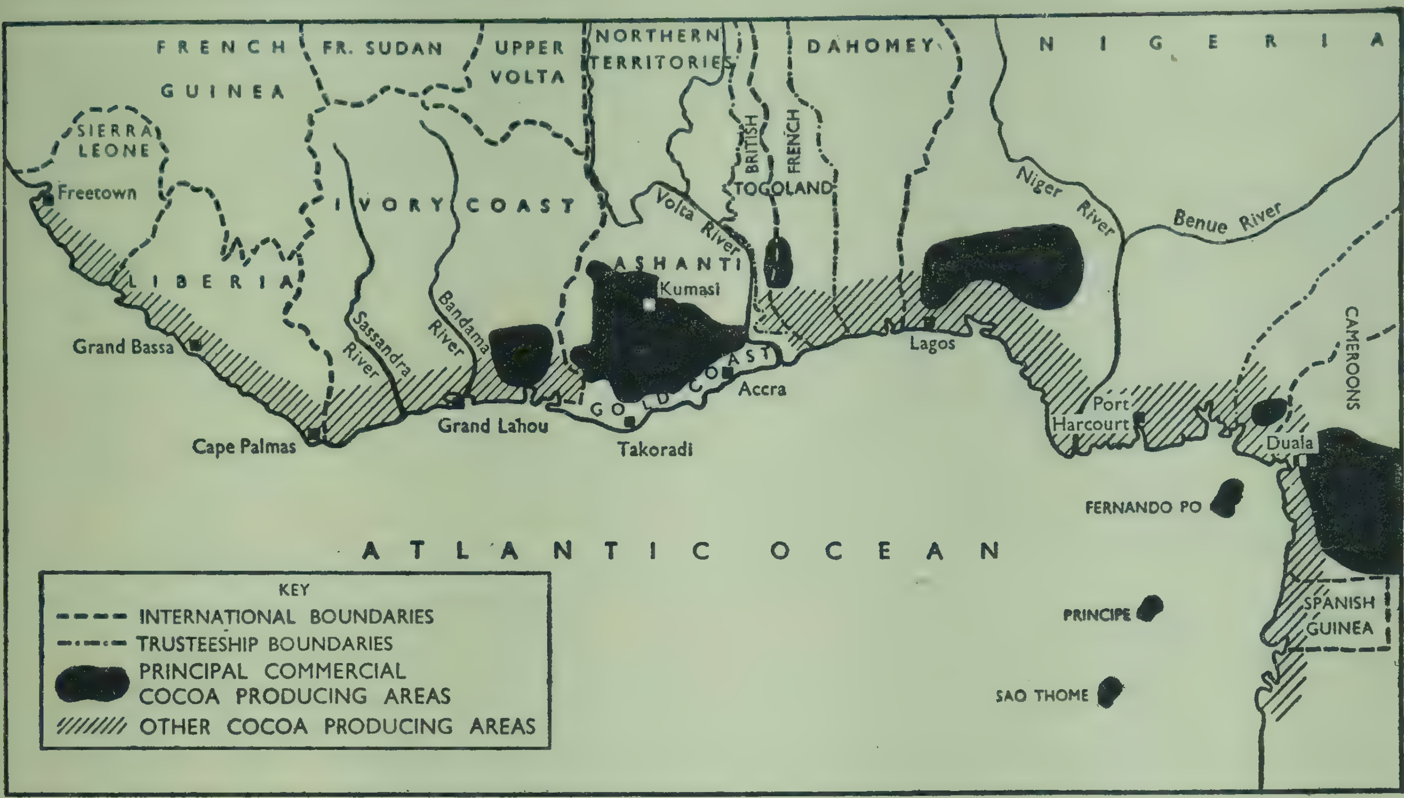

FIG. 10. WEST AFRICA

FIG. 11. CENTRAL AND SOUTH AMERICA

TABLE B

WORLD PRODUCTION OF RAW COCOA (*in thousand Long Tons*)

	1938/39		1949/50		1954/55		
	Prod.	% of Total	Prod.	% of Total	Prod.	% of Total	10-year Avge. 1941/51
AFRICA							
Gold Coast ..	298	*37·9*	249	*32·5*	220	*27·1*	228·0
Nigeria	116	*14·7*	99	*12·9*	89	*11·0*	97·0
Ivory Coast ..	54	*6·9*	60	*7·9*	73	*9·0*	36·0
French Cameroons	31	*3·9*	44	*5·8*	58	*7·1*	39·0
Fernando Po and Rio Muni ..	14	*1·8*	17	*2·2*	21	*2·6*	15·0
São Tomé and Principe ..	11	*1·4*	8	*1·0*	8	*1·0*	8·0
French Togoland	10	*1·3*	3	*0·4*	16	*2·0*	3·0
Sierra Leone ..	—	—	2	*0·3*	2	*0·2*	1·0
Belgian Congo ..	1	*0·1*	2	*0·3*	3	*0·4*	1·5
Other Africa ..	4	*0·5*	1	*0·1*	2	*0·2*	1·0
TOTAL: Africa ..	539	*68·5*	485	*63·4*	492	*60·6*	429·5
AMERICA							
Brazil	137	*17·4*	159	*20·8*	168	*20·7*	125·0
Ecuador	15	*1·9*	21	*2·8*	27	*3·3*	18·0
Venezuela ..	15	*1·9*	14	*1·8*	16	*2·0*	17·0
Colombia ..	4	*0·5*	11	*1·4*	15	*1·9*	10·0
Costa Rica ..	7	*0·9*	4	*0·5*	7	*0·9*	5·0
Mexico	1	*0·1*	8	*1·0*	10	*1·2*	4·0
Panama	6	*0·8*	3	*0·4*	2	*0·2*	2·0
Bolivia	2	*0·3*	3	*0·4*	3	*0·4*	3·0
Other America	1	*0·1*	1	*0·1*	5	*0·6*	1·0
TOTAL: America	188	*23·9*	224	*29·2*	254	*31·2*	185·0
WEST INDIES							
Dominican Republic ..	30	*3·8*	33	*4·3*	35	*4·3*	26·0
Trinidad and Tobago ..	7	*0·8*	7	*0·9*	9	*1·1*	5·5
Grenada	4	*0·5*	3	*0·4*	3	*0·4*	3·0
Jamaica	2	*0·3*	1	*0·1*	3	*0·4*	2·0
Cuba	3	*0·4*	3	*0·4*	2	*0·2*	3·0
Haiti	2	*0·3*	2	*0·3*	2	*0·2*	2·0
Other West Indies	1	*0·1*	1	*0·1*	1	*0·1*	1·0
TOTAL: W. Indies	49	*6·2*	50	*6·5*	55	*6·7*	42·5
ASIA AND OCEANIA							
Ceylon	4	*0·5*	2	*0·3*	3	*0·4*	2·0
Indonesia ..	2	*0·2*	1	*0·1*	1	*0·1*	1·0
New Hebrides ..	2	*0·3*	1	*0·1*	1	*0·1*	1·0
Western Samoa ..	2	*0·3*	2	*0·3*	4	*0·5*	2·0
Other Asia and Oceania ..	1	*0·1*	1	*0·1*	3	*0·4*	0·5
TOTAL: Asia and Oceania ..	11	*1·4*	7	*0·9*	12	*1·5*	6·5
WORLD TOTAL ..	787	*100·0*	766	*100·0*	812	*100·0*	663·5

EFFECT OF PRICES ON PLANTING

A rise from very low prices to high prices naturally stimulates planting, but conditions in West Africa make it difficult to assess the extent to which high prices have been responsible for increased production at any one time. Here, plantations under peasant culture do not come into bearing till they are from ten to fifteen years old, and though extensive planting has continued, pests and diseases, especially virus diseases, have wrought such damage that they have affected production very considerably and in this way have masked the results of new plantings. Annual production in the Gold Coast alone has fluctuated from 192,000 tons to 278,000 tons within a period of three years.

The main factor in halting the upward trend in world production is undoubtedly the effect of pests and diseases. Annual world production in recent times has fluctuated by as much as 137,000 tons. Although an abnormally dry season may seriously depress production in Brazil, and to a lesser degree in West Africa, an abnormal distribution of rainfall, creating favourable conditions for the fungus *Phytophthora*, is the chief reason for violent downward annual fluctuations in output.

Capsid pests reduce yields in West Africa by many thousands of tons, although it is not known to what extent they are responsible for annual fluctuations. Virus disease in the Gold Coast, Nigeria, and the Ivory Coast has killed off large areas of cocoa, and ants have killed millions of trees in Brazil.

It is surprising that in view of the heavy toll taken by pests and diseases in the important cocoa-producing countries, production has been kept up to its present level. It is strikingly obvious that even partial control of any one of them would lead to a subtantial rise in production.

NEW GROWING AREAS

Successive years of high prices have encouraged the search for new areas where cocoa could be grown, and there are still such areas in the world. Large areas exist in West Africa and the Americas where cocoa-planting could be extended. Asia and the Pacific could between them make considerable contributions to the market, if and when more land is put under cocoa.

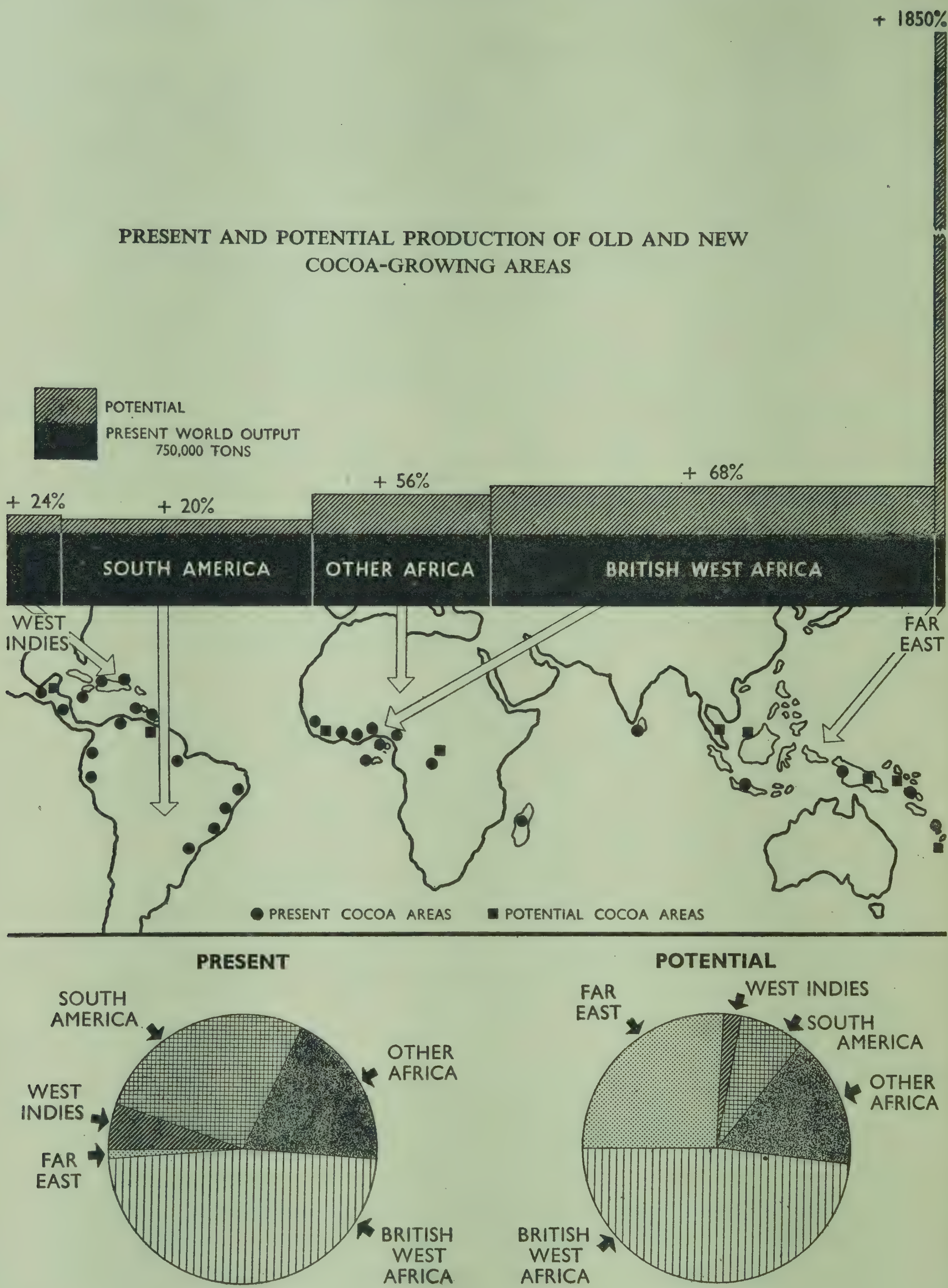
+ 1850%
PRESENT AND POTENTIAL PRODUCTION OF OLD AND NEW COCOA-GROWING AREAS
POTENTIAL
PRESENT WORLD OUTPUT 750,000 TONS
+ 24%
+ 20%
+ 56%
+ 68%
SOUTH AMERICA
OTHER AFRICA
BRITISH WEST AFRICA
WEST INDIES
FAR EAST
PRESENT COCOA AREAS
POTENTIAL COCOA AREAS
PRESENT
SOUTH AMERICA
WEST INDIES
FAR EAST
OTHER AFRICA
BRITISH WEST AFRICA
POTENTIAL
FAR EAST
WEST INDIES
SOUTH AMERICA
OTHER AFRICA
BRITISH WEST AFRICA

FIG. 12

The rehabilitation or rejuvenation of plantations which have declined in yield, and the replanting of land that, for one reason or another, has ceased to grow cocoa, will be of importance in stepping-up production in some countries.

When cocoa plants of higher yielding capacity become readily available, the effect on production should be considerable.

EFFECT OF IMPROVED CULTURAL METHODS

Again, general improvements in farm and plantation practice among peasant communities will in course of time help to raise the yield per acre. The present unmethodical systems whereby the trees are not planted in lines and are too closely spaced make farm hygiene extremely difficult. If these improvements are accompanied by the application of shading and by the maintenance of a good level of fertility through manuring or other means, they will have important results in raising yields in those countries where production is mainly in the hands of peasant communities.

The general conclusion must be that, notwithstanding the fact that a wide application of present knowledge to the plantation industry would lead to a marked increase in production, the scientist must provide economic means of keeping pests and diseases under better control, if the additional several hundred thousand tons for which world markets are waiting are to materialize.

COCOA PRODUCTS

Preparations of cocoa have been used for food and confectionery for 150 years, and as beverages for at least four centuries. Consumption was greatly increased when in the early 1800s it was discovered how to separate the cocoa butter from the powder. Hitherto, the high fat content of the natural bean had been counterbalanced by the addition of arrowroot and other farinaceous substances. The discovery in 1876 that the main products of the cocoa bean could be combined with milk to make milk chocolate was one of the important events in the history of cocoa manufacture. This is the form in which chocolate is most popular to-day.

The two products of the cocoa bean which are of interest to the manufacturer are the cocoa butter, which constitutes 56 per cent of good beans, and the cocoa powder. In the manufacture of chocolate, the roasted nibs are ground into a mass to which extra cocoa butter (extracted in the manufacture of cocoa powder for drinking) and sugar are added, and a further admixture of considerable quantities

of milk solids is made in the manufacture of milk chocolate. Cocoa butter has a distinctive flavour and a low melting-point, which make it especially suited for moulding and for covering biscuits, nuts, fruits, etc., a quality essential in the manufacture of attractive sweetmeats. Cocoa powder is in wide use as a beverage and for the flavouring of other foodstuffs. The aim of the modern manufacturer is to make full use of both powder and butter.

Chocolate and cocoa contain both protein and fat, and their highly concentrated food value has been shown in their use as Service rations, and during expeditions to various parts of the world where human endurance on the minimum amount of food has been put to the test and where the food value is high in relation to bulk and weight to be carried.

Cocoa butter is also used in the manufacture of cosmetics and pharmaceutical preparations. Theobromine, a mildly tonic drug, is extracted from the shell, and the shell itself is used in cattle foods.

Although cocoa butter is superior to other fats for the manufacture of confectionery, less expensive substitutes are sought when the price is high. This use of alternatives is a serious threat which can only be met by increasing the supplies of raw cocoa.

LOCAL PROCESSING

Raw cocoa is nearly all exported from the tropical countries of origin to those in temperate climates where it is manufactured. Manufacture of chocolate in the form in which it is usually consumed presents difficulties in hot countries. Producing countries now retain about 10 per cent of world production, mainly for the purpose of extracting cocoa butter.

WORLD CONSUMPTION

Average world consumption during the five years 1949–53 was 728,000 long tons, the United States and the United Kingdom consuming half the world production between them, but the U.S.A. consumes twice as much as the U.K.

The Netherlands, Germany, and France are the next in importance with a total requirement of 150,000 long tons per annum. Switzerland, Sweden, and Belgium together take 65,000 to 70,000 tons per annum, while Russia, Canada, Spain, Italy, and Australia have an aggregate intake of 61,000 tons per annum.

TABLE C

WORLD CONSUMPTION OF RAW COCOA

(*in thousand Long Tons*)

	1930		1950		1954	
	Consumption	*% of Total*	*Consumption*	*% of Total*	*Consumption*	*% of Total*
AMERICA:						
United States ..	165	*33·9*	268	*34·1*	194	*26·8*
Canada ..	7	*1·4*	17	*2·2*	12	*1·7*
Brazil	—	—	29	*3·7*	17	*2·3*
Argentina ..	5	*1·1*	5	*0·7*	8	*1·1*
Colombia ..	9	*1·8*	22	*2·8*	24	*3·3*
Mexico	2	*0·4*	6	*0·8*	8	*1·1*
Dominican Repub.	—	—	5	*0·7*	11	*1·5*
Other America ..	3	*0·6*	12	*1·5*	14	*1·9*
TOTAL: America ..	191	*39·2*	364	*46·5*	288	*39·7*
EUROPE:						
United Kingdom	57	*11·7*	126	*16·1*	114	*15·7*
Netherlands ..	51	*10·5*	66	*8·4*	55	*7·6*
Germany (W.) ..	75	*15·4*	50	*6·4*	69	*9·5*
Germany (E.) ..	—	—	—	—	6	*0·8*
France	37	*7·6*	65	*8·3*	50	*6·9*
Spain	8	*1·7*	10	*1·3*	16	*2·2*
U.S.S.R. ..	3	*0·6*	10	*1·3*	25	*3·5*
Switzerland ..	7	*1·5*	8	*1·0*	10	*1·4*
Sweden	4	*0·8*	8	*1·0*	7	*1·0*
Italy	7	*1·5*	10	*1·3*	18	*2·5*
Belgium ..	8	*1·7*	8	*1·0*	6	*0·9*
Czechoslovakia	7	*1·5*	5	*0·7*	3	*0·4*
Poland	5	*1·0*	3	*0·3*	3	*0·4*
Austria	6	*1·2*	6	*0·8*	7	*1·0*
Denmark ..	3	*0·6*	6	*0·8*	2	*0·3*
Norway.. ..	2	*0·4*	4	*0·5*	4	*0·6*
Hungary ..	2	*0·4*	—	—	1	*0·1*
Portugal ..	1	*0·2*	1	*0·1*	1	*0·1*
Ireland	—	—	4	*0·5*	5	*0·7*
Other Europe ..	5	*1·0*	4	*0·5*	4	*0·6*
TOTAL: Europe ..	288	*59·3*	394	*50·3*	406	*56·2*
TOTAL: Australia and New Zealand	5	*1·0*	12	*1·5*	11	*1·5*
TOTAL: Africa ..	—	—	8	*1·0*	11	*1·5*
TOTAL: Asia ..	3	*0·6*	5	*0·7*	8	*1·1*
WORLD TOTAL ..	487	*100·0*	783	*100·0*	725	*100·0*

Averages: 1941–1954 (14 years), 657,000 long tons;
1950–1954 (5 years), 732,000 long tons.

TABLE D

COCOA PROCESSED IN COUNTRIES OF ORIGIN
(*in thousand Long Tons*)

	1949	*1953*
Brazil	18	25
Colombia*	11	14
Gold Coast	1	12
Mexico	5	8
Dominican Republic	4	8
Others	10	9
	49	76

* Colombia also imports cocoa for processing for local consumption.

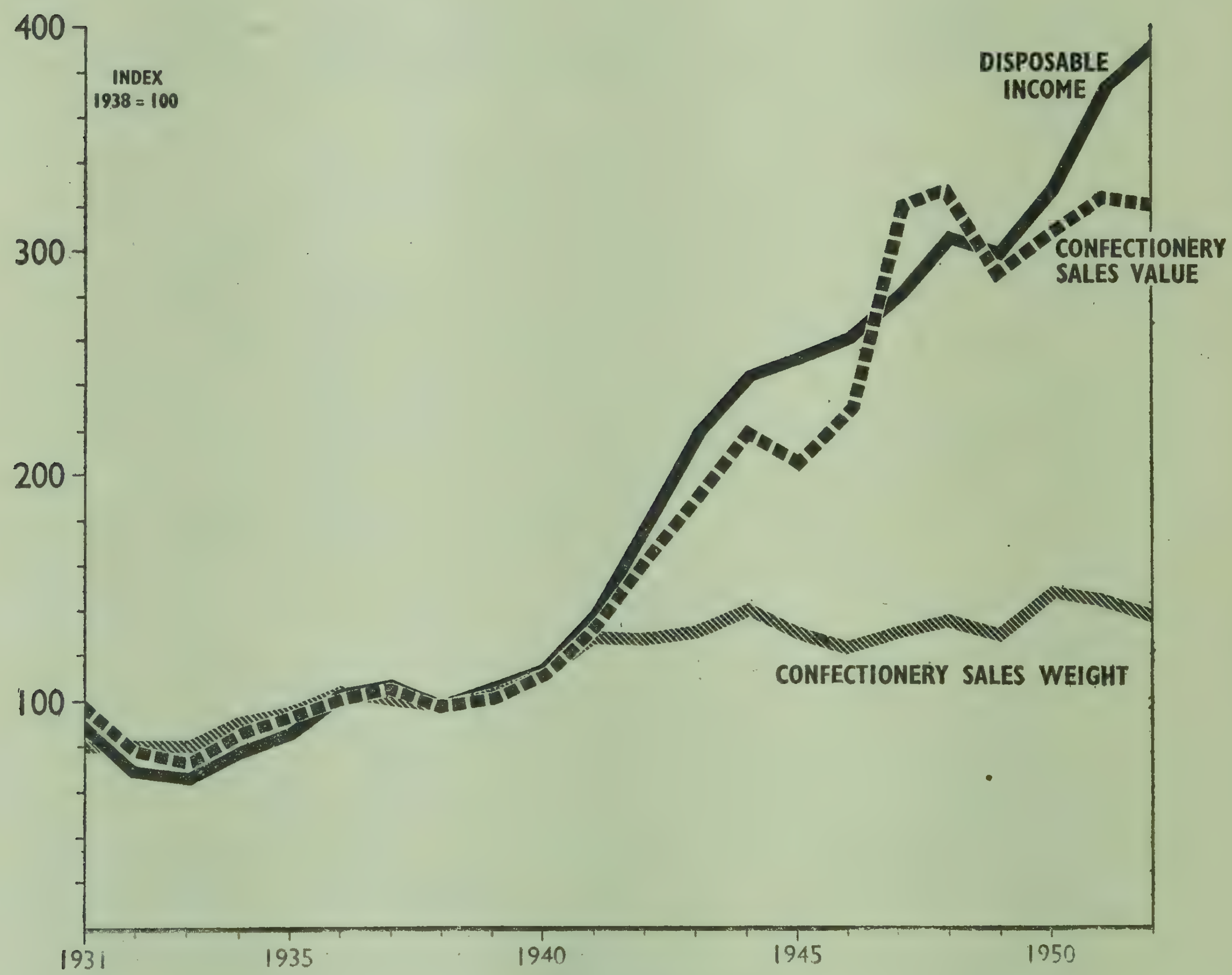

FIG. 13

RELATION OF DEMAND FOR CONFECTIONERY
(INCLUDING COCOA PRODUCTS) TO PROSPERITY IN U.S.A.

CONSUMPTION IN U.S.A.

The market in the U.S.A., which takes from 250,000 to 260,000 tons per annum, is of particular interest. It has already been noted, in discussing production, that American consumption has not expanded in proportion to its much increased population and continued high level of prosperity, but has actually contracted. It is disturbing that the country which has hitherto bought annually upwards of a third of the total production of raw cocoa should show a progressive recession when a vastly increased consumption might have been expected. This contraction is primarily due to the use of cheaper substitutes for cocoa butter, mainly other vegetable fats, and the diversion of money to other products, e.g. ice-cream and caramels. When cocoa butter became too expensive, the use of substitutes was forced on the manufacturers in order that they might be able to market their products profitably in competition with rival commodities.

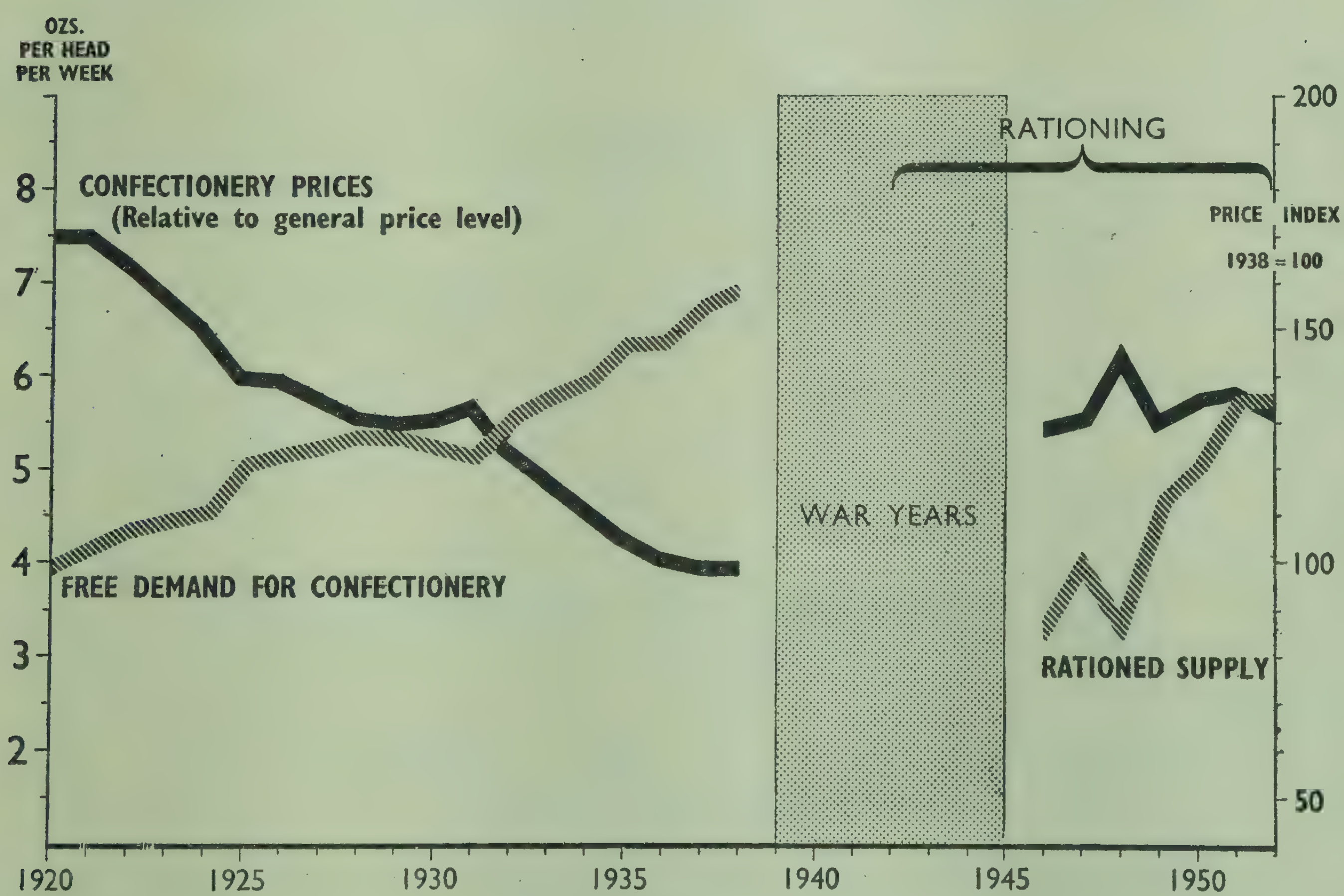

FIG. 14

RELATION OF DEMAND FOR CONFECTIONERY (INCLUDING COCOA PRODUCTS) TO PRICE LEVEL IN U.K.

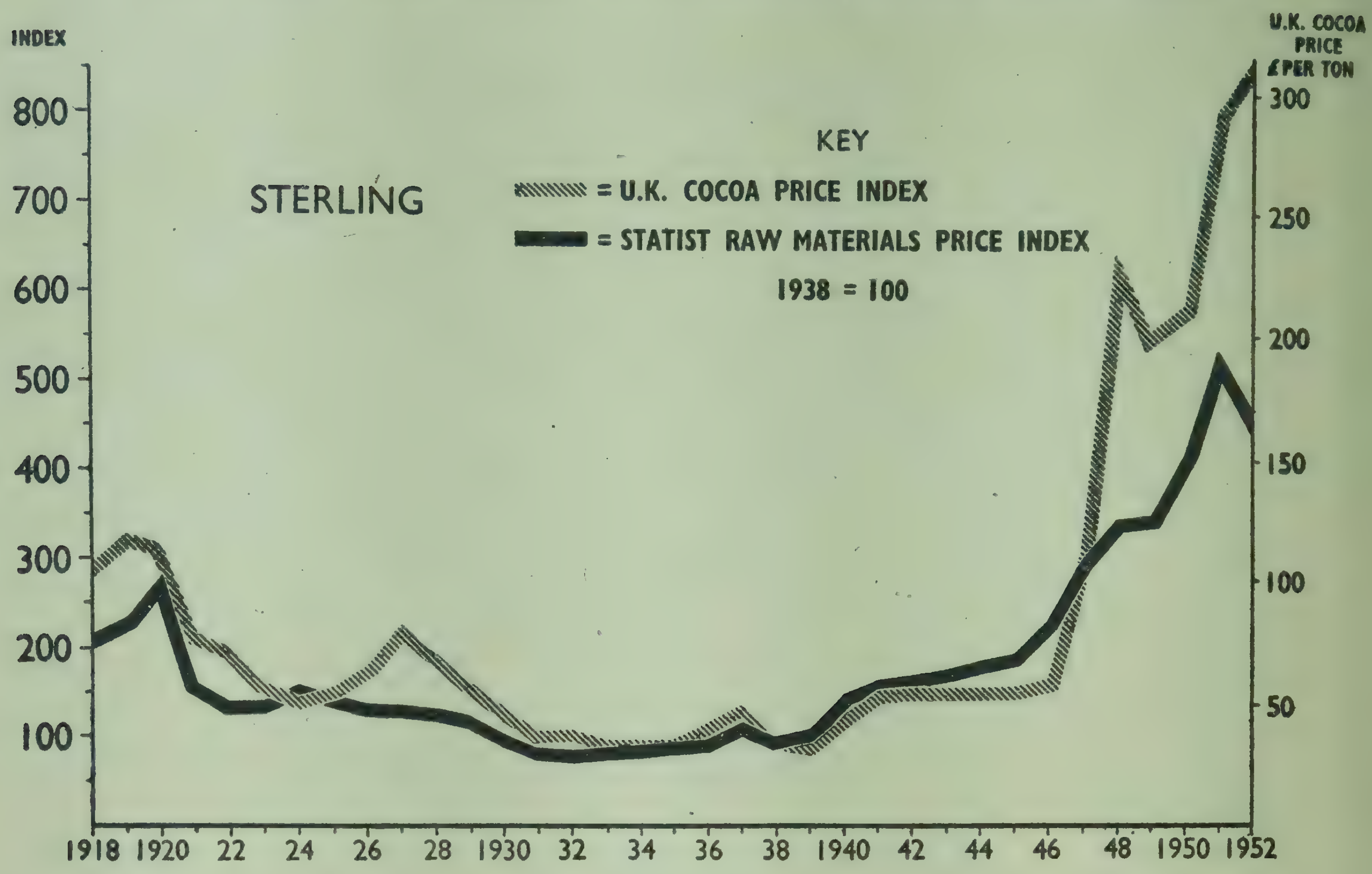

FIG. 15

STERLING PRICE OF RAW COCOA COMPARED WITH RAW MATERIALS PRICE INDEX, 1918–52
The price for the 1953–54 season's crop rose to £550 per ton.

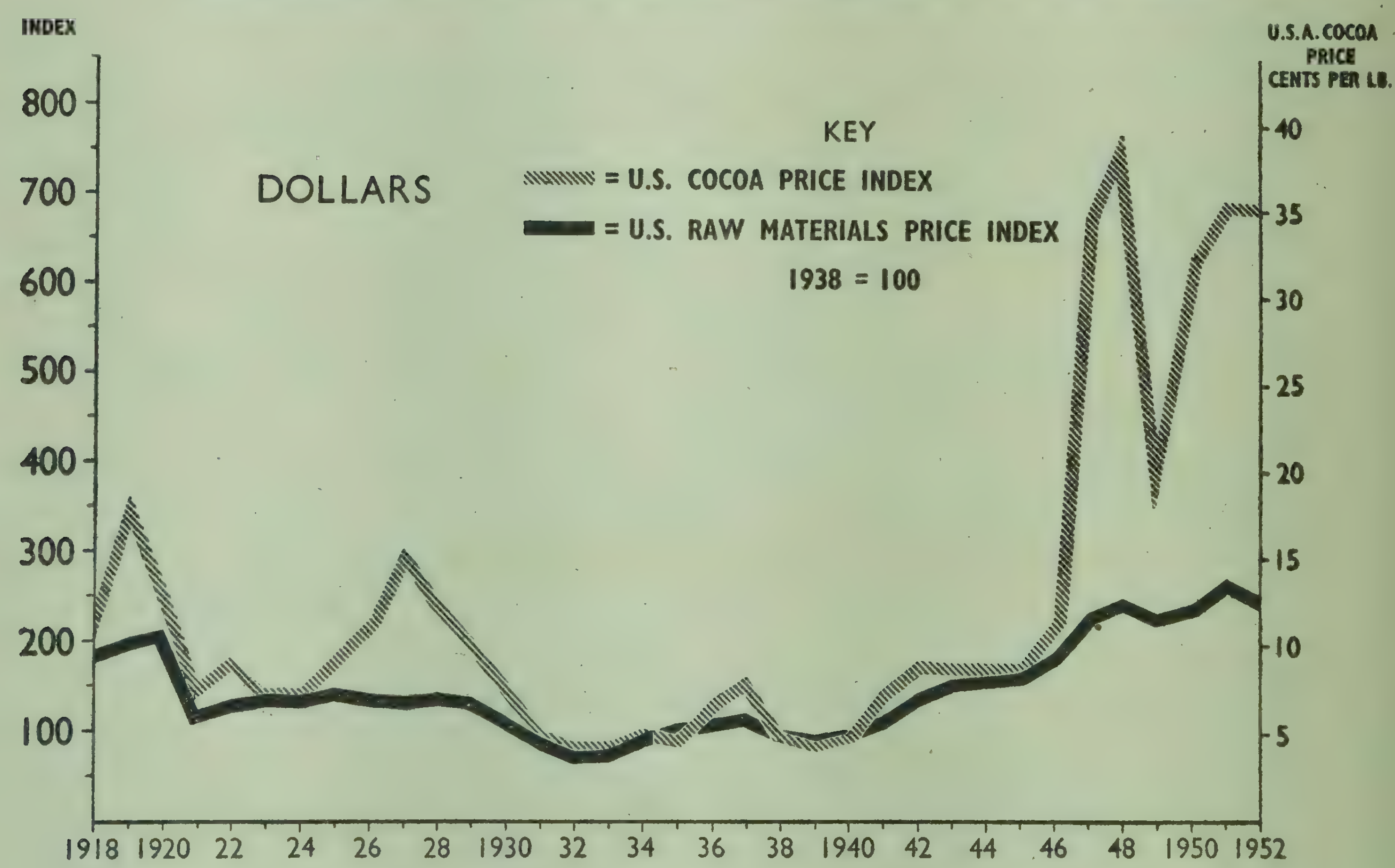

FIG. 16

DOLLAR PRICE OF RAW COCOA COMPARED WITH INDEX OF U.S. PRICE INDEX OF RAW MATERIALS, 1918–52
The price for the 1953–54 season's crop rose to 65 cents per lb.

CONSUMPTION IN U.K.

Consumption in the United Kingdom during the war and post-war years was held in check by rationing and the limitation of sugar supplies for manufacture. More ample supplies of sugar and unrestricted sales have made for greatly increased consumption. It is in fact higher than before 1939 despite the competition of tobacco, ice-cream, various forms of entertainment, and other outlets for the public's "impulse-spending."

CONSUMPTION ELSEWHERE

Consumption in the Netherlands, Germany, and France has returned to pre-war or near pre-war levels. Consumption in Russia and Italy has increased since the war, but in Canada and Australia it has fallen off markedly. Russia and Germany (and perhaps Japan) may considerably increase their intake in the future, and the raising of living standards in backward countries will not be without effect on the demand for cocoa products.

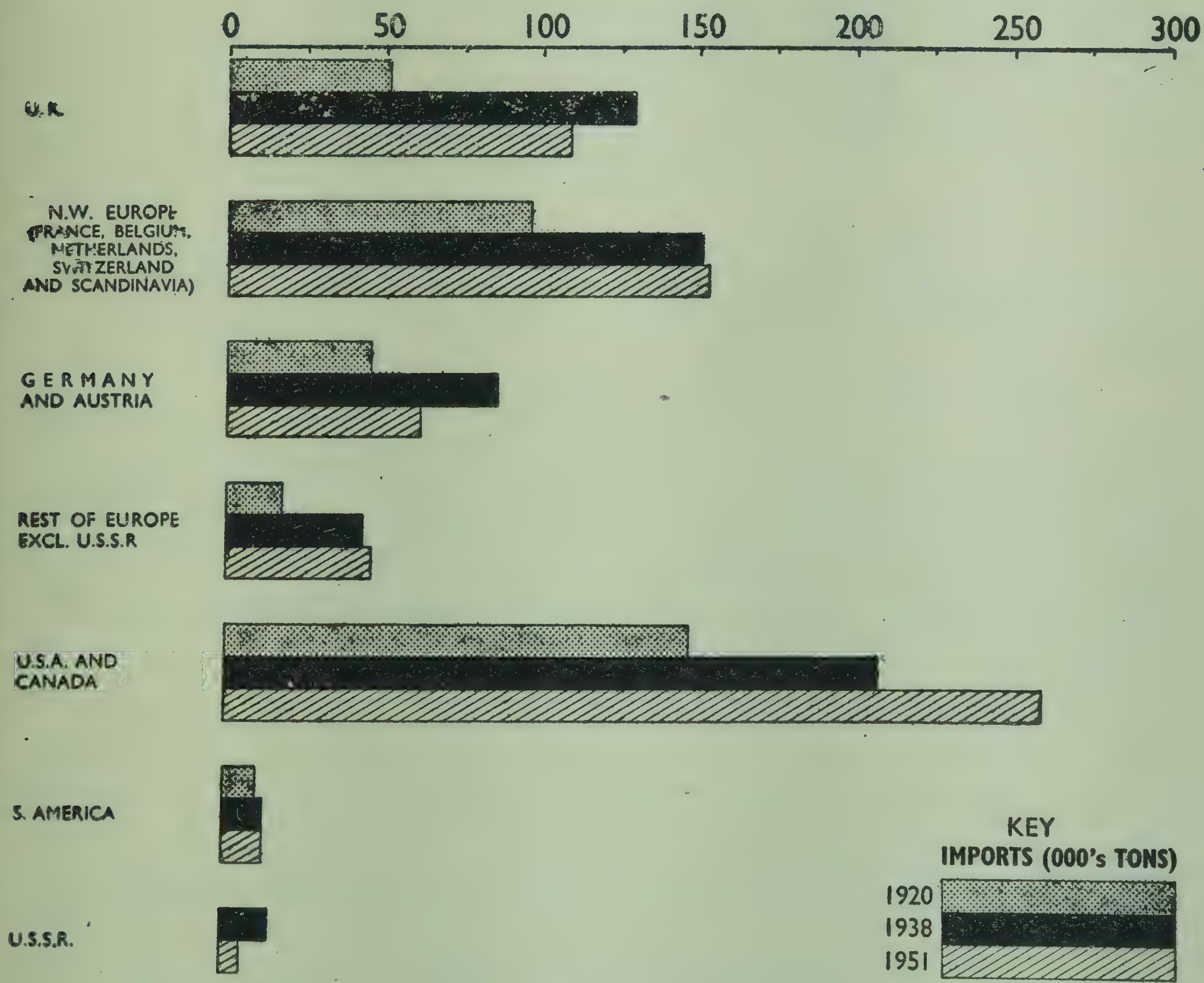

FIG. 17

EXPANSION OF DEMAND FOR RAW COCOA IN A FREE ECONOMY

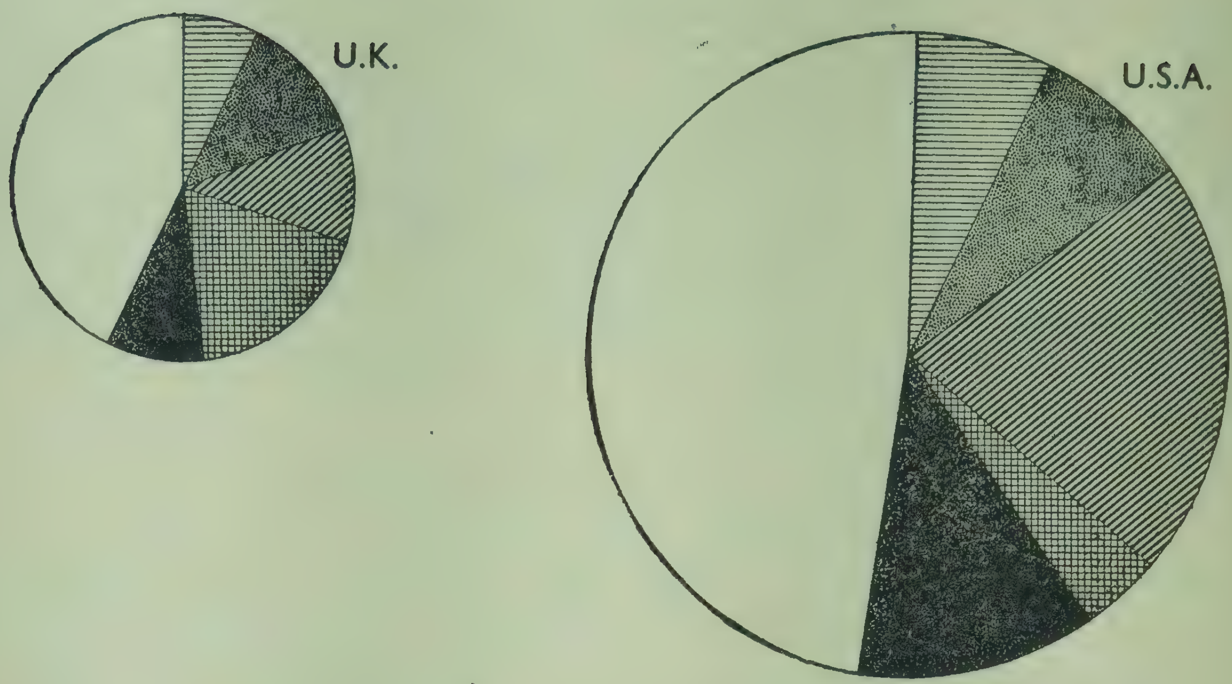

FIG. 18

	U.K. %	U.S.A. %
Cocoa, Drinking Chocolate, etc.	7	7
Moulded Chocolate ..	12	8
Chocolate Candy Bars ..	11	21
Chocolate Assortments ..	18	4
Covering Chocolate, etc. ..	9	12
Sugar Confectionery, etc. ..	43	48

COCOA PRODUCTS ACCOUNT FOR MORE THAN HALF
OF THE CONFECTIONERY OUTPUT IN UNITED KINGDOM AND U.S.A.

CONCLUSION

However the figures for consumption are reviewed and analysed, one satisfactory conclusion may be reached, namely, that the consumption of the manufactured products of cocoa is a well-established habit which, given adequate supplies of raw cocoa, will increase rather than diminish.

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Appendix 1

SOIL SURVEYS

THE first requirement for growing cocoa in any part of the world is the availability of a suitable soil.

For a long time past soil surveys have been recognized in the U.S.A. as essential for schemes of land-planning and land-use. New Zealand was among the first of the countries of the British Commonwealth to make use of soil surveys, and they are now being conducted in most British colonial territories. Larger countries may employ their own teams or departments of soil survey, or have survey officers as a division of the Department of Agriculture. Some countries with small Departments of Agriculture and with large extents of territory to survey find it more convenient to employ teams to carry out this work on contract.

SOIL SURVEYS IN THE GOLD COAST

The Gold Coast was the first country in Africa to form a Division of Soil Surveys within the Department of Agriculture, and this later developed as an independent department under C. F. Charter.

The need for assessing the potentialities of the forest zone, especially as regards land suitable for further planting of cocoa, was appreciated by the farmers and Chiefs in the Gold Coast, and in 1948 a grant of £150,000 was made from the funds of the Cocoa Marketing Board to provide the necessary laboratories, buildings, and staff to conduct a soil survey.

It was recognized that in such a relatively undeveloped country, natural regions determined by drainage systems of river basins provided a convenient framework on which soil maps could be based. It was therefore planned to take each drainage basin in turn. The following is an outline of the methods evolved by Charter:

The first step is a preliminary survey to obtain a general idea of the soils, soil associations, and their distribution. Information obtained in regard to communications and sites for possible field bases is noted.

The next two steps are described by C. F. Charter as follows:

Reconnaissance Soil Surveys

Reconnaissance soil surveys are carried out by teams of African assistants taking observations along parallel traverse lines a mile and a quarter apart. A small team of land surveyors marks the starting points of traverse lines, which usually commence along roads or trails, in advance of the reconnaissance teams. These teams consist of six assistants, with one or two spares, and a dozen or so labourers. A reconnaissance team comprises a direction-giver with prismatic compass and ranging poles, who is responsible for the cutting of traverse lines; a distance-measurer supplied with a Gunter's chain, who also keeps a running commentary on the topographical features traversed; a vegetation-recorder who maps the vegetation of a circular area of one-quarter acre at each furlong; and three soil-recorders, one of whom is the team leader, who are equipped with spades, soil chisels, and augers and who, at every furlong, describe inspection holes and collect soil and rock specimens for later examination. Inspection holes are sunk to a depth of four feet and the following data collected for each soil layer observed: thickness; colour; presence or absence of organic matter; texture, that is whether sandy or clayey, based on feel; consistency based on ease of augering, etc.; presence or absence of gravel or concretions, etc., etc.

Detailed Soil Surveys of Sample Strips

Within each soil association mapped by reconnaissance methods, detailed soil surveys are made of representative sample strips measuring two furlongs in width and a mile in length. Traverse lines are run half a furlong apart throughout the length of these strips and observations are taken along these lines and along short offsets at right angles to them so that information can be collected to enable contour, soil, and vegetation maps to be prepared on a scale of ten inches to the mile. In each soil mapped a six-foot profile pit is dug and samples of each layer making up the soil are carefully collected for purposes of correlation and laboratory analysis. This work is performed by detailed soil survey teams which are similarly constituted to those employed on reconnaissance, but their members have additional training and experience, and make use of more advanced techniques.

At the headquarters or main base the soil samples are collected and correlated, and from the information derived from the field maps are made which show the boundaries of the various soils.

It will be appreciated that a soil survey on this scale requires careful planning. Much detailed accurate work is needed before the final stage is reached where maps are produced on which future land-planning and land-use will be based.

Appendix II

COSTS OF COCOA CULTURE ON ESTATES AND PEASANT FARMS

GENERAL CONSIDERATIONS IN ESTATE COSTING

On organized cocoa estates both capital cost and recurrent expenditure vary from country to country. Among the controlling factors which vary between countries and even between different parts of the same country are the natural conditions. These include soil fertility, which helps to determine the length of the period a tree takes to come into bearing, and the relative length of the dry season, which dictates whether the crop can be sun-dried or must be dried artificially. This factor also affects weeding costs, which are lower in a country with a long dry season than in one where the dry season is short. Costs of materials and equipment depend (*inter alia*) on the distance they must be transported. Skill in management also enters largely into estate costs.

Production costs per ton are of course related to yield per acre—the higher the yield, the lower the proportionate cost and, naturally, the greater the profit.

Labour varies in efficiency, but the time taken by experienced labourers under supervision is roughly the same for any given task on any plantation. The "man-day," therefore, is a convenient unit for the calculation of labour-costs.

The costs per acre on the peasant farms in West Africa and on peasant small-holdings in other parts of the tropics are of a different order from those on estates. Equipment and buildings for the West African peasant farmer are relatively simple, and the cocoa is mainly harvested in the dry season and sun-dried. Weeding, farm sanitation, and general attention to the cocoa trees are on less intensive lines than are the rule on an estate. The main costs in peasant culture are for labour, some of which may be wholly or partly supplied by the family, or it may be entirely hired.

While capital and recurrent costs per acre are higher on the organized estate than in large- or small-scale peasant culture, the out-turn of cocoa per acre on a good estate is usually greater. For example, the Lukolela estates in the Belgian Congo are intensively tended under careful supervision. They are well provided with good housing for personnel, good buildings for fermenting and drying, and with good equipment generally.

ESTIMATED LABOUR REQUIREMENTS OF PLANTATION DEVELOPMENT FROM VIRGIN BUSH (AGRICULTURAL OPERATIONS ONLY) FOR OIL PALMS AND RUBBER

Man-days per acre

Oil Palms

Average spacing—30 ft. × 30 ft. triangular = 55 palms to the acre (Planting holes $2\frac{1}{2}$ ft. × $2\frac{1}{2}$ ft.)

Development:	
Survey (initial prospecting)	2
Brushing, felling and lopping	45
Lining and holing	8
Clearing planting lines and paths	23
Nurseries	22
Planting	8
Cover crops	3
Sundry labour	9
TOTAL DEVELOPMENT	120

Maintenance to Bearing Stage:	*Per annum*
General weeding	5
Pruning	—
Replacements	3
Upkeep of paths	3
Control of pests and diseases	2
Nurseries	2
Sundry labour	5
	20 × 4 yrs. = 80
TOTAL DAYS	200

Rubber

Average spacing—22 ft. × 11 ft. = 180 to the acre. (Planting holes 1 ft. × 1 ft.)

	Seedling Trees	*Bud Grafts*
Survey (initial prospecting)	2	2
Brushing, felling, and lopping	45	45
Lining and holing	10	10
Clearing planting lines and paths	45	45
Nurseries	12	7
Planting	6	6
Cover crops	3	3
Sundry labour	8	8
Add costs for budding	—	6
	131	132

	Per annum	*Per annum*
General weeding	13	13
Pruning	2	2
Replacements	3	3
Upkeep of paths	2	2
Control of pests and diseases	4	4
Nurseries	—	—
Sundry labour	1	1
	yrs. 25 × 5 = 125	*yrs.* 25 × 6 = 150
TOTAL DAYS	256	282

ESTIMATED LABOUR REQUIREMENTS OF PLANTATION DEVELOPMENT FROM VIRGIN BUSH (AGRICULTURAL OPERATIONS ONLY) FOR BANANAS AND COCOA

Bananas

Various spacings, e.g.:
11 ft. × 11 ft. triangular = 415 trees per acre
12 ft. × 12 ft. triangular = 348 trees per acre
14 ft. × 14 ft. triangular = 256 trees per acre
(Planting holes 1 ft. × 1 ft.)

DEVELOPMENT:	
Survey	2
Tree cutting	2
Felling underbush	10
Lining and holing	14
Planting	15
Final felling	30
Clearing lines	12
Draining in the field	2
Sundry labour	3
TOTAL DEVELOPMENT	90

MAINTENANCE TO BEARING STAGE:	*Per annum*	
General weeding	14	
Pruning	2	
Fertilizing	1	
	17 × 1 yr. =	17
TOTAL DAYS		107

Cocoa

Average spacing—10 ft. × 10 ft. triangular = 500 trees per acre.
(Planting holes 1 ft. × 1 ft.)
(Planted under natural shade)

	Stake Planting	*Basket Planting*
Survey	2	2
Clearing underbush	6	6
Lining and holing	14	14
Clearing planting lines and paths	18	18
Planting	4	18
Mulching	1½	1½
Thinning-out forest shade	8½	8½
	54	68

	Per annum		*Per annum*	
General weeding	12		12	
Pruning	½		½	
Replacements	1½		1½	
Control of pests and diseases	2		2	
Progressive thinning out of forest shade	5		5	
	21 × 4 *yrs.* =	84	21 × 4 *yrs.* =	84
TOTAL DAYS		138		152

ESTABLISHING PLANTATION CROPS ON LARGE ESTATES

The estimated man-days per acre for different operations given in the accompanying table are based on the analysis of plantation records of the land-clearing and development operations for growing the more important crops under a wide range of conditions. These data provide a basis for calculating the costs that may be expected on well-organized estates.

Cocoa is one of the cheaper crops to establish and it also has the advantages that it can be stored in the tropics for a limited period and is easily transported. Bananas are cheaper to establish, it is true, and come into bearing within twelve to fifteen months after planting; on the other hand, they must be put into cool storage or shipped immediately they are picked, and specially constructed ships are required for transporting them to the market.

CAPITAL AND OVERHEAD COSTS ON LARGE ESTATES

The examples given in the foregoing analysis are for labour costs only, and, as examples of costs for large cocoa plantations on the same scale are not available, it may be of interest to quote the distribution of capital costs for a 5,000-acre oil palm plantation. The installations in an oil palm plantation include an expensive mill which would represent 25 per cent of the capital costs, so the figures given below would have to be adjusted according to the type of installation envisaged for fermenting and drying the cocoa.

	per cent
Development and maintenance labour	30
Development and maintenance overheads (Supervision, transport, tools, etc.)	25
Housing for senior staff and labourers	32
Stores and other buildings	4
Hospital facilities	3·5
Roads	2
Transport	2·5
Wharfage	1
	100

BELGIAN CONGO

LABOUR COSTS

At the Lukolela estates in the Belgian Congo the method of establishing plantations makes use of existing forest trees for shade, those with a suitable canopy being selected. In the first year the brushwood and felled trees are piled in rows twenty feet apart and lines of cocoa are planted, the plants being spaced ten feet apart

between the rows of piled wood. After two years from the time of first planting, the wood has rotted down and further rows of cocoa are planted so that the cocoa trees are finally spaced 10 ft. by 10 ft. throughout.

Operation	*Man-days per acre*	
1st year:		
Marking out the land	1	
Clearing brushwood	3	
Lining and holing	10	
Felling and clearing	62	
Nursery work	10	
Planting	5	
		91
2nd year:		
Weeding	7	
Care of plants	2	
		9
3rd year:		
Weeding	7	
Care of trees	1	
Clearing between the rows	7	
Lining and holing	14	
Nursery work	10	
Planting	2	
Thinning and planting shade	1	
		42
4th year:		
Weeding	13	
Care of trees	12	
		25
Total		167

MAINTENANCE OF AN ESTABLISHED ESTATE

The following figures from Lukolela estates indicate the cost in man-days per acre for maintaining a mature plantation. The yield is assumed to be about 600 lb. per acre.

Operation	*Man-days per acre*
4 weedings	5·3
Harvesting; field sanitation, capsid control, care of cocoa and shade trees	18·2
Opening pods	3·2
Fermentation and drying	2·4
Bagging cocoa	0·3
Gathering wood for fuel	1·1
	30·5

WEST INDIES

Replanting Old Estates

The following is an example of the costs of replanting old cocoa fields in Grenada with cocoa plants raised from rooted cuttings. All the old cocoa trees were felled, banana shade was established, but permanent shade trees were not planted. The field was manured with 25 tons of pen manure, which was forked into the soil.

The plants grown from rooted cuttings were provided free by the Government and there are therefore no nursery costs. When women were employed, woman-days have been converted to man-days on the basis of 5 men being equal to 6 women.

Operation	*Man-days per acre*	
1st year:		
Felling old cocoa trees	18	
Manuring and forking	34	
Lining and holing	13	
Planting temporary shade	17	
Planting cocoa	6	
Draining	20	
Weeding	45	
		153
2nd year:		
Weeding	15	
Supplying and pruning	3	
Adjusting shade	4	
Draining	8	
		30
3rd year:		
Manuring and forking	34	
Weeding	20	
Care of trees	4	
Temporary shade	4	
Draining	8	
		70
4th year:		
Weeding	15	
Pruning and reaping	10	
Temporary shade	4	
Draining	8	
		37
		290

A similar example from Trinidad is given for comparison. Here again the old cocoa trees and immortelles were felled and temporary shade was provided by bananas and tannias. Mineral, and not pen,

manure was applied. Immortelles were replanted to provide permanent shade.

Operation	*Man-days per acre*	
1st year:		
Clearing and felling	15	
Lining and holing	12	
Planting temporary shade and immortelles	15	
Planting cocoa	7	
Draining	17	
Weeding	16	
Manuring	3	
		85
2nd year:		
Weeding	24	
Care of plants, pruning and supplying	17	
Regulating shade	3	
		44
3rd and 4th years:		
Weeding	24	
Care of plants	8	
Mulching and regulating shade	7	
Draining	4	
Manuring	3	
	46 × 2 =	92
		221

In these examples from Grenada and Trinidad, the food crops providing the temporary shade and ground cover were partly consumed on the estate and partly sold. The income from food crops helped to offset expenses in the early years.

On one estate in Grenada the whole cost of establishing a cocoa field with clonal plants was repaid at the end of five years, one-third of the income coming from the sale of food crops. The capital outlay cannot always be repaid so quickly. Where the cost of transporting the food crops is high, little or no profit may be derived from their sale.

WEST AFRICA

Costs under Peasant Culture

Cocoa is established in the Gold Coast in several different ways, three of which may be considered from the point of view of costs.

(*a*) Where the village community or family has cleared land for

the purpose of raising food for the family and a surplus for sale, and has planted cocoa in the food farm.

(*b*) Where a farmer secures the right to a considerable area of land for the purpose of establishing a cocoa plantation, the forest is cleared and usually planted with cocoyams as ground cover, and plantains to provide lateral shade, for the cocoa for several years. When the forest is cleared and the land hoed, cocoa is planted among the cocoyams and plantains, which are intended to be catch crops and to offset to some extent the cost of establishing the cocoa plantation. This method presupposes that the plantation is either near a road to allow of the cocoyams and plantains being transported to the market by lorry, or not so far away from the road as to make the cost of transporting them by headload prohibitive.

(*c*) Where an enterprising farmer secures an area of land at some distance from a motorable road, so that the growing of other crops on a large scale for sale would be uneconomic, and cocoa alone is planted. Here there would be less clearing, especially of the large forest trees, as a number of these would be left to shade the cocoa.

Cocoa with Family Food Crops

In considering (*a*), the economic and social study of the village of Akokoaso in the Gold Coast, made by Beckett in the early 'thirties, in which he investigated labour requirements of cocoa, will be taken as the basis for calculation. He estimated that the annual labour requirements of young farms was 23·8 man-days per acre per annum. This included work on clearing the forest, brushing (weeding and cutting-back of young forest growth), planting and harvesting food crops, and planting cocoa.

The cocoa farms under investigation took ten years to come into bearing, so that total labour requirement for raising the food crops and bringing the cocoa to the bearing stage was 240 man-days per acre.

In this same study, the figures arrived at for labour expended on farms in bearing was 25·8 man-days per acre per annum, made up as follows:

Operation	*Man-days per acre per annum*
Weeding	8·2
Harvesting	15·6
Carrying	1·4
Sundry	0·6
	25·8

These figures could be used in several ways to arrive at the cost of production of one ton of cocoa under the particular conditions which apply at Akokoaso. A great deal of the cocoa of the Gold Coast has been established under these conditions, and it is therefore interesting to make an estimate of what the possible cost per ton might be.

If a generous view is taken and the figure of 240 man-days incurred over the first ten years is charged to cocoa, although it did in fact include food crops as well, we have an average figure of 24 man-days per acre per annum.

The costs in labour are reckoned over a thirty-year period. The cost in man-days during the last twenty years after the cocoa trees have come into bearing would be 25·8 per acre per annum. In order to account for the 24 man-days per annum used in the first ten years, 12 man-days per acre per annum may be added to this 25·8, bringing the cost per acre per annum to 37·8 man-days.

Annual yields of cocoa for a great part of the Gold Coast have been accepted as from 350 to 600 lb. per acre.

If a low average yield of 350 lb. is taken for the twenty-year bearing period, this will make due allowance for the lower yields during the first few years after the cocoa has come into bearing.

At a yield of 350 lb. per acre, it will take 6·4 acres to provide 2,240 lb. (or one ton) of cocoa.

Accordingly, 242 man-days (6·4 × 37·8) would be required to produce a ton of cocoa during the first twenty years of bearing, and at 4s. per day would amount to £48 per ton approximately.

After thirty years, when the labour costs of the first ten non-bearing years had, so to speak, been written off, the labour cost would drop to 165 man-days (25·8 × 6·4) per ton and, at 4s. per day for labour, this would represent £33 per ton.

Now, assuming a higher yield of 500 lb. of cocoa per acre, then the cost of producing a ton during the first twenty years would be 4·5 acres × 37·8 man-days × 4s. = £34 approx. On the same basis as before, the cost of producing a ton of cocoa after thirty years would be 4·5 acres × 25·8 man-days × 4s. = £23 approx.

Inter-planting with Food Crops

On the basis of method (*b*) the following figures give some indication of costs and returns from land which is planted as a cocoa farm but inter-planted with economic catch crops to offset the expenses incurred during the early years.

The assumption is that the land is in high forest and a ten-acre cocoa farm is being established over a period of eight years.

			£	s.
1.	Partial felling of forest trees and clearing by contract ..		45	0
2.	Purchase of plantain suckers for planting at 16 ft. by 20 ft. apart—say, 1,700 suckers at 5s. per 100		4	5
3.	Cocoyams for seed—usually taken from another farm or bought cheaply—say		2	0
4.	Cost of cocoa seed, 1,800 pods (with 35 beans per pod = 50,000 beans for planting three at a stand, equivalent to three loads of 60 lb. of dry cocoa)		12	0
5.	Planting cocoa (at stake), plantains and cocoyams—on contract		12	0
		£		
6.	1st weeding 8 months after planting	18		
	2nd weeding 16 months after planting	15		
	3rd weeding 22 months after planting	8		
		—	41	0
7.	A labourer-caretaker would be employed for part of the first year and the whole of subsequent years. Allowing £36 for the first year and £48 per annum for the subsequent seven years until the plantation comes into bearing, on the assumption that a farm receiving so much attention would bear at eight years from planting		372	0
8.	Mud and wattle house for labourer		30	0
9.	Cost of implements:	£ s.		
	2 felling axes at 12s.	1 4		
	6 cutlasses at 2s. 6d.	15		
	1 steel file	3		
	1 native grinding stone	2		
		——	2	4
10.	State fees for acquisition of lands at £1 per annum ..		8	0
11.	Allowing for contingencies and interest on borrowed money (a sum which may vary greatly)		150	9
			£678	18

The cost per acre to bring the cocoa into bearing on the above figures is about £68.

Returns might be of the following order.

The price received for plantains may vary from 2s. to 3s. 6d. or more per bunch, depending on whether they are far from or near the roadside. A modest price of 1s. 9d. per bunch is assumed for the purpose of this calculation to make generous allowance for costs of harvesting and possible head-loading to the roadside.

The farm is commonly cropped with plantains for five successive years. The second- and third-year crops are better than the first and by the fifth year there is a reduction in yield.

If an average yield of 1,200 bunches per annum is assumed (from

the original 1,700 stands) for four successive years, this gives a return of £420.

Cocoyams should give a yield of 400 lb. per acre for two successive years. This would be 8,000 lb. = 44 sacks (180 lb. per sack) at 20s. per sack = £44.

This represents a net return of £464 from the catch crops on the ten acres or £215 less than the original outlay during the first eight years.

The annual yield of cocoa per acre during the ninth and two subsequent years might be respectively 300, 400, and 400 lb. per acre, but allowing for the possibility that only eight out of the ten acres are well-established owing to bad soil or some other cause, there would be a total yield of $\frac{1,100 \times 8}{2,240} = 3{\cdot}9$ tons. At £150 per ton this would be a gross return of £584.

Cocoa as Sole Crop

According to the third method (*c*) high forest is cleared and no economic crops are planted apart from cocoa. Once the cocoa has come into bearing, the price levels for it are such that costs of bringing it into bearing are soon paid off and the investment becomes profitable.

These calculations may be said to be over-simplified in some respects. There are various difficulties encountered by the farmer, such as soil variations, incidence of disease, high losses through pests, insufficient or unfavourable distribution of rainfall and other factors which may reduce his gross returns, although his outlay may remain the same. In a country where there are so many variables in establishing and maintaining cocoa, any estimate of the costs of production and the returns can only be taken as a rough guide. It is nevertheless true that cocoa-growing is very profitable by peasant culture methods where the venture is even moderately successful.

Appendix III

PLANTS PER ACRE AT DIFFERENT SPACINGS

Planting distance in feet	*Area for each plant in square feet*	*No. of plants per acre*
4 × 4	16	2,722
5 × 5	25	1,742
6 × 6	36	1,210
7 × 7	49	889
8 × 8	64	680
9 × 9	81	537
10 × 10	100	435
11 × 11	121	360
12 × 12	144	302
13 × 13	169	257
14 × 14	196	222
15 × 15	225	193
16 × 16	256	170
17 × 17	289	150
18 × 18	324	134

Appendix IV

PREPARATION OF ROOTED CUTTINGS

The following additional information may be found useful by the planter who wishes to prepare his own rooted cuttings:

PREPARATION OF COMPOSTED SAWDUST

Medium grain sawdust of mixed hardwoods is composted by mixing it with farmyard manure in the proportion of 5 of sawdust to 1 of manure. In order to improve the aeration of this mass coarse grass or brushwood is inserted. The heap is soaked with water or a 1 per cent solution of sulphate of ammonia, which will accelerate decomposition, and it is covered with elephant grass or sugar cane trash to conserve moisture. If the heap is kept moist the sawdust is composted into a dark brown or blackish material in seven to eight months. It is then sifted and used as a rooting-medium.

PREPARATION OF THE POTTING-MIXTURE

Two parts of sifted soil are mixed with one part of sawdust. To each bushel of this mixture is added 4 oz. of sulphate of ammonia, 2 oz. of muriate of potash, and ½ oz. of superphosphate.

The best results are obtained when the mixture is prepared ten days before it is used.

The weight of a basket containing soil and plant ready for the field is 6 to 7 lb. A 3-ton lorry will take 800 basketed plants. Care has to be taken to prevent undue drying of the plants while being transported in dry weather.

From the time the plants are first put in the baskets until they are planted in the field, the number of baskets used will work out on the average at about two-and-a-half baskets per plant. The number of times the baskets will have to be renewed will depend on the material used in making them.

MATERIALS REQUIRED FOR ESTATE PROPAGATOR WITH A CAPACITY OF 10,000 PLANTS PER ANNUM

	Approx. quantities
1. *Construction*	
Concrete for floor = 1,070 sq. yds. by 3 in.	89 cub. yds.
2 rooting-bins	1,588 hollow tiles
2 hardening-bins	1,100 hollow tiles
Wooden uprights, 4 in. by 4 in. by 10 ft.	65
Perforated pipe: ½-in.	180 ft.
¾-in.	216 ft.
Water-pipe: ½-in.	200 ft.
¾-in.	100 ft.
In addition:	
Concrete for roads and drainage.	
Pipe fittings—valves, elbows, unions, crosses.	
Materials for glasshouse: glass and aluminium sheeting.	
Boulders for drainage in bins: coarse	40 cub. yds.
do. fine	12 cub. yds.
Overhead shade: rafters, 2 in. by 2 in.	1,200 ft.
do. netting	1,400 sq. yds.
Wooden frames, 3 ft. 3 in. by 3 ft.	120

Some of these items will depreciate fairly rapidly and will need to be renewed after two to three years.

2. *Materials used in propagation (per annum)*	
Fertilizer for nursery	16 cwt.
do. plants	24 cwt.
Baskets (2½ per plant)	25,000
Domestic cloth	240 sq. yds.
Hormone	10 grams
Hose	120 ft.

Appendix V

COCOA FERMENTATION

THE importance to the manufacturer of the proper fermentation of cocoa has been stressed in Chapter VIII. The following paper advances a new theory of the process and embodies the result to date of research carried out by Mr. R. V. Wadsworth and Dr. G. R. Howat in the laboratories of Messrs. Cadbury Brothers Ltd. at Bournville. It is reproduced with their permission and that of the editors of *Nature* (Macmillan & Co. Ltd.), in which it first appeared.

PROPOSED METHOD FOR FERMENTING SMALL QUANTITIES

An attempt has been made to solve the problem of the fermentation of small quantities of cocoa beans. A solution to the problem is particularly urgent at the present time when botanists have made available a large number of new varieties of cocoa. What has been lacking is a satisfactory method of fermenting beans from only one or two pods from each variety, to enable an early and accurate assessment to be made of their quality and acceptability to chocolate manufacturers.

For our experiments, pods of West African Amelonado cocoa were flown from the Gold Coast by commercial airline. Usually they arrived at Bournville about twenty-four to thirty hours after leaving Accra. On arrival the pods were swabbed with a solution of a quaternary ammonium compound to remove surface moulds and other organisms. Tests for viability were made on a few beans by staining technique, and by germination tests. It was found that no chocolate flavour could be developed from dead beans, and the time of death was an important factor.

Two methods of fermentation were developed. In the first method an apparatus similar to that described by De Witt was used. The pods were opened under aseptic conditions and the beans were sprayed with a mixed culture of a yeast, *Hansenula anomala*, and an acetic acid-producing organism, *Bacillus orleanense*.

Knapp (ref. 3, pp. 17, 30) states that both these organisms are found frequently in commercial fermentations. The inoculum was about 20 million organisms suspended in 10 ml. of Ringer's solution. In accordance with the practice adopted in good commercial fermentations, the beans were well stirred every second day.

Fig. 19 shows the fermentation curve aimed at, using this method. It will be noted that during the first $3\frac{1}{2}$ days the temperature should not exceed 38° C. During the last three days the temperature should be about 50 to 51° C.

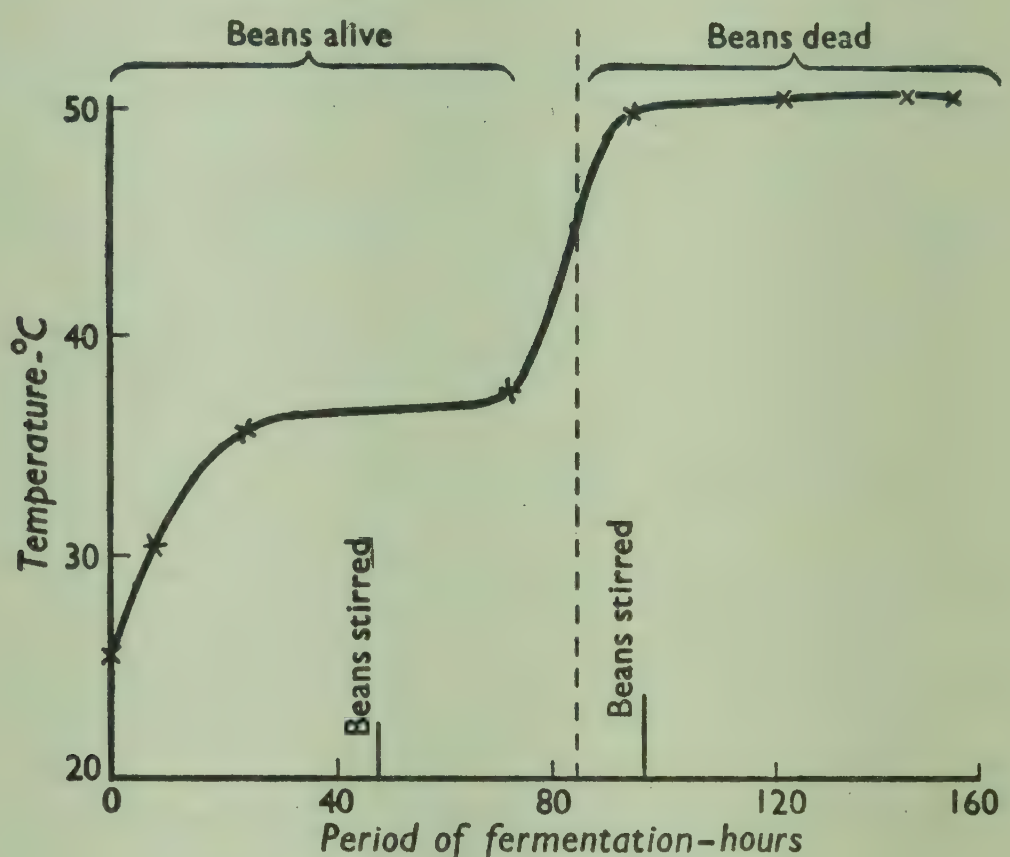

FIG. 19

At the end of the fermentation period, the beans were dried in a cabinet maintained at a high humidity to simulate West Afrcian conditions. Heat was supplied by a 100-watt electric light bulb. The temperature was not thermostatically controlled and it varied between 45° and 50° C. Under these conditions, drying to a moisture content of about 6 per cent took five or six days.

Beans prepared by this method and using the temperature limits shown in Fig. 19 were generally brown in colour and had cotyledons with an open texture. A few beans showing some purple colour in the cotyledons were found in most of the experiments. It was found that the beans from these fermentations, after roasting and shelling, could be made into chocolate with a good chocolate flavour.

The second method involved the use of "aseptic fermentations". In these, the beans were maintained at any desired temperature in a water-bath or incubator. The pulp was not removed; but the beans were sprayed with a very dilute solution of a quaternary ammonium compound to prevent the growth of organisms in the pulp during "fermentation". This method is capable of general application, and it is independent of the chance presence of desirable (or undesirable) micro-organisms in the atmosphere or the use of pure cultures. Suitably modified, we have been able to ferment successfully single beans by this method. In our later experiments the aseptic method was used exclusively, and we consider it less liable to variation than the traditional method.

Details of the aseptic method are as follows. The beans are removed from the pods under aseptic conditions and placed in sterile glass vessels. If the beans from two or three pods are being fermented, tall 600-ml. beakers are suitable. The beans are then sprayed with a solution containing 300 p.p.m. of a quaternary ammonium compound. The beakers are fitted with false bottoms prepared by placing inverted watch glasses on a framework of glass rod. Any liquid produced during "fermentation" consequently drains away from the beans. The top of each beaker is covered with several thicknesses of aluminium foil and this is kept in place with a tight rubber band.

The beakers are placed in a water-bath or incubator kept at a temperature of 35° C. and allowed to remain there for a period of 84 hours (3½ days). During this period a considerable volume of carbon dioxide gas is produced and it is essential that this should be removed. It can be done in one of two ways. A quantity of potassium hydroxide solution can be placed under the watch glass at the bottom of the beaker, or the beans can be thoroughly stirred after 24, 48, and 72 hours, and at 84 hours. The first method is probably the better; but it will be remembered that in no circumstances should the potassium hydroxide solution come into contact with the beans.

The beaker containing the beans is then transferred to a water-bath or incubator at 50° C. and kept at this temperature for a period of 72 hours (3 days). Although production of carbon dioxide at 50° C. is limited to the first few hours (until the death of the bean), it is desirable that even this small quantity of gas be removed. This can be done either by stirring after 24 hours at 50° C. or by the use of potassium hydroxide solution.

At the end of the period the "fermented" beans are plump, and when cut exude a small quantity of dark brown liquid. The cotyledons are open and can readily be separated from each other. They are a pale watery purple colour, possibly with a background of brown.

The beans are now transferred to a drying cabinet and dried under the same conditions as those fermented naturally. When dry, the beans will be found to have a loose shell and, on cutting, the cotyledons will be found to be dark brown in colour and to have an open texture. After roasting and shelling they can be made into chocolate which has a good chocolate flavour.

FACTORS INVOLVED IN FERMENTATION

Recent experiments on the fermentation of small quantities of West African Amelonado cocoa in these laboratories have directed attention to several aspects of the changes involved in fermentation which do not appear to have been noted previously. At least three factors play a part in the development of chocolate flavour.

The first is the germination processes in the bean during the first part of fermentation. This seems to have been accorded no importance in previous work. Indeed, Knapp (ref. 3, p. 134) states that "until the bean is killed no change takes place in the interior, so that it is desirable to raise the temperature rapidly to accomplish this". Our experiments have shown that this view is incorrect. Beans which have been killed by cold—24 hours in a refrigerator at 1° to 1·5° C.—and then fermented using pure cultures of organisms, or prepared by the aseptic method, do not produce anything resembling a chocolate flavour. Also, when beans are maintained at a temperature of 50° C. for several days without a prior period at a germinating temperature, no chocolate flavour is developed.

The second factor is that the beans must be maintained at a temperature of about 50° C. for several days after the initial germination period. If this is omitted and the beans maintained at around 35° C. for five days, they give either a mild flavour which is reminiscent of caramels, or have a slight liquorice character when made into chocolate. In addition, the colour of such beans after drying is not brown, it is purple. At higher temperatures the degree of purple remaining in the finished beans is less; but it is our experience that even when a temperature of 45° to 46° C. is maintained instead of 50° C., some purple background is present and there is bitterness in the chocolate produced. It should be noted that the temperatures used in our aseptic fermentations approximate roughly to those observed in good commercial fermentations. The nature of the changes produced during this period has not been studied by us in detail. They are, however, undoubtedly associated mainly with changes in the polyphenols, as has been noted by Forsyth.

The third factor is the removal of carbon dioxide from the air

around the fermenting beans. It is well known, of course, that carbon dioxide is produced in fermenting cocoa. There appears, however, to be no published record that large quantities of carbon dioxide are produced by the bean itself—as distinct from fermentation of the pulp—during the early stages of fermentation.

Our experiments have shown that when fermented under aseptic conditions, the carbon dioxide content of the atmosphere around the cocoa beans may rise as high as 90 per cent during the first three days. In fermenting single-bean samples, we have found that a single cocoa bean (dry weight 1·2 gm.) produces up to 10 ml. carbon dioxide at N.T.P. during the early stages of fermentation. There is apparently no liberation of carbon dioxide after the bean dies.

In certain experiments an atmosphere of carbon dioxide was maintained around the beans during the period they were held at 50° C. or during drying. In each case it was found that the chocolate prepared from such beans was unpleasant and had no chocolate flavour.

It is interesting to note that in good commercial fermentations the practice is to turn the cocoa or to mix it every second day. This will have the desired result, if properly done, of removing the carbon dioxide.

Two other points have interested us. One is that during fermentation very little change takes place in the *p*H of the cotyledons. In our fermentations, using pure cultures of organisms, we found that the *p*H of the pulp fell from about 4 to 2·5. There was no similar fall in the *p*H of the cotyledons; here a slight reduction, from 5·5 to 5, was all that was noted.

This point is of particular interest in that it has been frequently suggested that the flavour of fermented beans is affected by the character of the fermentation which it has undergone, and that the esters formed during fermentation may permeate the testa and pass into the cotyledons. In the light of our findings, this seems unlikely.

The other point which interested us was the gap in temperature that exists between the thermal death-point of the organisms which occur in commercial fermentations and the maximum temperature recorded in a fermenting heap. The thermal death-point of most organisms occurring in commercial fermentations is 43° to 44° C. as observed by Rombouts, The maximum temperature recorded in good fermentation practice is, however, usually 50° to 51° C. It appears possible that the heat produced by the enzymic processes in germination is sufficient to raise the temperature of the whole fermenting mass sufficiently to bridge the gap between 44° and 51° C.

A fuller account of these experiments is in course of preparation

and will be published elsewhere. We are indebted to the Directors of Cadbury Brothers, Ltd. for permission to publish this communication.

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Appendix VI

PREPARATION OF BORDEAUX MIXTURE

BORDEAUX mixture is one of the oldest fungicidal mixtures but it is still one of the most effective for the control of black pod disease on cocoa. The quality of the mixture will depend on the materials used and the method of preparation. A 1 per cent mixture is normally used and is made up of 5 lb. of copper sulphate and 5 lb. of quick-lime in 50 gallons of water. This is sometimes referred to as a "5-5-50" mixture.

A good quality quicklime or slaked lime should be used. It is difficult to store in the tropics and should not be kept longer than three months.

In Nigeria calcium carbide has been used successfully as a substitute for lime, 2½ lb. being used in place of 5 lb. of lime.

The lime and copper sulphate are dissolved separately in water in a wooden tank which has two compartments of different sizes. In the smaller compartment 10 lb. of lime are dissolved in 20 gallons of water and agitated. In the larger compartment 10 lb. of copper sulphate are dissolved in 80 gallons of water. The crystals of copper sulphate should be placed in a small bag or on a perforated tray suspended just under the surface of the water.

The two solutions are mixed in the tank of the spraying machine, the lime being put into the tank first. During the mixing the individual liquids must be agitated continuously. Although copper sulphate solution is corrosive the mixture is not, so the mixing tank may be made of metal.

The mixture should be used within a few hours of preparation.

Appendix VII

COCOA PRICE EQUIVALENTS

New York (c.i.f.)	United Kingdom (c.i.f.)		New York (c.i.f.)	United Kingdom (c.i.f.)	
cents per lb.	s.	d. per cwt.	cents per lb.	s.	d. per cwt.
20	160	0	30	240	0
21	168	0	31	248	0
22	176	0	32	256	0
23	184	0	33	264	0
24	192	0	34	272	0
25	200	0	35	280	0
26	208	0	36	288	0
27	216	0	37	296	0
28	224	0	38	304	0
29	232	0	39	312	0
			40	320	0

Appendix VIII

GLOSSARY OF TERMS

Callus: Tissue developed by plants in response to wounding.

Cherelles: Pods in an early stage of development.

Chlorosis: Yellowing of leaves and other green parts due to lack of chlorophyll.

Chupon: Upright form of branch of cocoa tree which has the leaves spirally arranged. The growth of a chupon ends in a jorquette. The first main stem and suckers are chupons.

Clone: The progeny of a single parent produced vegetatively.

Fan: Form of branch with leaves arranged in two opposite ranks.

Flush: Cocoa trees put forth new shoots several times a year; each new shoot is termed a flush.

Hormone: Chemical compound produced in one tissue and transferred to another, where it produces a profound effect.

Hyper-parasite: Parasite of a parasite.

Jorquette: The point at which a chupon forks into three, four, or five fan branches.

Lenticel: Small pore in woody stem.

Mycorrhiza: Fungus associated with the roots of plants. The association is for the mutual benefit of fungus and plant.

Nibs: Manufacturer's term for dried and shelled cocoa beans broken into small pieces.

Ovary: Structure containing the ovules.

Ovule: Cells that after fertilization develop into a seed.

Pedicel: Stalk of an individual flower.

Peduncle: Stalk of inflorescence or flowering shoot.

Petiole: Leaf stalk.

Relative humidity: Percentage relation between the amount of moisture actually present in the air at a given temperature and the amount which saturated air would contain at the same temperature.

Stipule: Small leaf-like structures borne in pairs at base of petiole.

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